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of Transportation

Federal Motor Carrier
Safety
Administration

# 2010-2011 Hours of Service Rule
# Regulatory Impact Analysis
## RIN 2126-AB26

By
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Federal Motor Carrier Safety Administration

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# REGULATORY ASSESSMENT FOR THE PROPOSED HOURS-OF-SERVICE (HOS) RULE

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## ACRONYMS

| | |
|---|---|
| APA | Administrative Procedure Act |
| BLS | Bureau of Labor Statistics |
| CFS | Commodity Flow Survey |
| CMV | Commercial motor vehicle |
| D.C. | District of Columbia |
| DFACS | Driver Fatigue, Alertness and Countermeasures Study |
| DOT | Department of Transportation |
| FARS | Fatality Analysis Reporting System |
| FHWA | Federal Highway Administration |
| FMCSA | Federal Motor Carrier Safety Administration |
| FR | Federal Register |
| FTEs | Full-time equivalent employees |
| GDP | Gross domestic product |
| GVW | Gross vehicle weight |
| GVWR | Gross vehicle weight rating |
| HOS | Hours of Service |
| IFR | Interim Final Rule |
| LCM | Logistics Cost Model |
| LTCCS | Large Truck Crash Causation Study |
| LTL | Less-than-truckload |
| NAICS | North American Industry Classification System |
| NHS | National Highway System |
| NHTSA | National Highway Traffic Safety Administration |
| NPRM | Notice of Proposed Rulemaking |
| OOS | Out of service |
| OSA | Obstructive sleep apnea |
| OTR | Over-the-road |
| PATT | Parents Against Tired Truckers |
| RIA | Regulatory Impact Analysis |
| RODS | Records of duty status |
| TIFA | Trucks Involved in Fatal Accidents |
| TL | Truckload |
| TOT | Time-on-task |
| UCR | Unified Carrier Registration |
| UMTIP | University of Michigan Trucking Industry Program |
| UMTRI | University of Michigan Transportation Research Institute |
| U.S. | United States |
| VIUS | Vehicle Inventory and Use Survey |
| VSL | Value of a Statistical Life |
| VSLY | Value of a Statistical Life Year |
| VMT | Vehicle miles traveled |

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# EXECUTIVE SUMMARY

This Regulatory Impact Analysis (RIA) provides an assessment of the costs and benefits of potential changes in Department of Transportation (DOT) Federal Motor Carrier Safety Administration (FMCSA) Hours of Service (HOS) regulations. The HOS regulations address the number of hours that a commercial motor vehicle (CMV) driver may drive, and the number of hours a CMV driver may be on duty before rest is required, as well as the minimum amount of time that must be reserved for rest and the total number of hours a driver may be on duty in a "work-week."

This analysis considers and assesses the consequences of four potential regulatory options. Option 1 is to retain the 2008 HOS rule. Option 1 is the no-action alternative, which would retain the provisions of the 2008 HOS rule. All costs are relative to Option 1. Options 2 through 4 limit daily duty time to 13 (from 14 hours), require at least one break during the duty day (none is currently required), and limit the use of the 34-hour restart provision to once every 168 hours with at least 2 nights off duty. Options 2 through 4 differ only in driving time allowed between 10-hour breaks. Option 2, one of the alternatives being proposed, limits allowable daily driving to 10 hours, the driving limit that existed prior to the 2003 rule. Option 3, the other alternative being proposed, retains the 11 hours of driving allowed under the current rule. Option 4 allows only 9 hours of driving, or 1 hour less than Option 2. This RIA compares the costs and benefits (in 2008 dollars) of Options 2 through 4 relative to the 2008 rule (i.e., Option 1) and assumes that there is full compliance with each of the options.

After profiling the affected industry, this RIA contains chapters describing the methodology for estimating the costs and benefits of HOS rule Options 2 through 4 relative to Option 1. To estimate the costs of operational changes, the basic approach is to follow the chain of consequences from changes in HOS provisions to the way they would impinge on existing work patterns in terms of work and driving hours per week, taking overlapping impacts of the rule provisions into account. Estimated changes in productivity are translated into changes in dollar costs using functions developed for the regulatory analyses of previous HOS rules. Summing the different cost components resulted in a total annualized cost of $1.0 billion for Option 2, $520 million for Option 3, and $2.3 billion for Option 4 (shown in Exhibit ES-1, and broken down by major provision assuming the provisions were added in the same order as shown in the table). Though these costs are estimated using impacts on industry productivity, they would most likely be passed along as increases in freight transportation rates, and then ultimately to consumers in increased prices for the goods that are transported by truck.

Safety benefits are estimated as the monetized reductions in crashes that can be anticipated to follow from reductions in fatigue. As discussed in the NPRM, the accurate indicator to measure safety benefits are reductions in crash risk because eliminating any hour of driving eliminates all increase in crash risk associated with that hour, not just the risk associated with fatigue coded ones. However, the Agency does not have enough data to determine relative crash risk for all types of crashes at each hour. Hence, we consider only risk associated with fatigue-coded crashes. The basic approach was to count the changes in hours worked and driven as a result of the regulatory options. Every hour of driving that is shifted from a driver working close to the limits to a more rested driver results in a reduction in expected fatigue-related crashes. The changes in crash risks were monetized using a comprehensive and detailed measure of the average damages from large truck crashes. This measure takes into account the losses of life (based on DOT's accepted value of a statistical life (VSL), recently set at $6 million), medical costs for injuries of various levels of severity, pain and suffering, lost time due to the congestion effects of crashes, and property damage caused by the crashes themselves. The monetary value of each of the effects thought to affect the safety of drivers was estimated under three different assumptions of the baseline level of fatigue involvements in crashes: 7 percent, 13 percent, and 18 percent. The total benefits resulting from improvements in the safety of long-haul drivers for Options 2 through 4 are shown below in Exhibits ES-2 through ES-4.

Exhibit ES-1. Total Annualized Costs for Options 2, 3, and 4
(Millions 2008$)

| Cost Category | Total – Option 2 | Total – Option 3 | Total – Option 4 |
|---|---|---|---|
| Reduction of Daily Work Hours | $190 | $190 | (combined with driving hour reduction) |
| Reduction of Daily Driving Hours | $590 | (no change in daily driving time) | $2,120 |
| Reduction Due to Restart Provisions | $210 | $290 | $150 |
| Training and Reprogramming Cost | $40 | $40 | $40 |
| Total Costs | $1,030 | $520 | $2,310 |

Exhibit ES-2. Safety Benefits (Dollars) for Option 2 (Millions 2008$)

| Assumed Percent of Crashes Due to Fatigue | Benefits Due to Reduced Acute Time on Task Effect | Benefits Due to Reduced Cumulative Time on Task Effect | Total Benefits Due to Reduced Crashes |
|---|---|---|---|
| 7 percent | $100 | $290 | $390 |
| 13 percent | $180 | $540 | $720 |
| 18 percent | $250 | $740 | $1,000 |

Note: Totals do not add due to rounding.

Exhibit ES-3. Safety Benefits (Dollars) for Option 3 (Millions 2008$)

| Assumed Percent of Crashes Due to Fatigue | Benefits Due to Reduced Acute Time on Task Effect | Benefits Due to Reduced Cumulative Time on Task Effect | Total Benefits Due to Reduced Crashes |
|---|---|---|---|
| 7 percent | $10 | $220 | $230 |
| 13 percent | $20 | $410 | $430 |
| 18 percent | $20 | $570 | $590 |

Note: Totals do not add due to rounding.

Exhibit ES-4. Safety Benefits (Dollars) for Option 4 (Millions 2008$)

| Assumed Percent of Crashes Due to Fatigue | Benefits Due to Reduced Acute Time on Task Effect | Benefits Due to Reduced Cumulative Time on Task Effect | Total Benefits Due to Reduced Crashes |
|---|---|---|---|
| 7 percent | $260 | $400 | $660 |
| 13 percent | $490 | $740 | $1,220 |
| 18 percent | $670 | $1,020 | $1,690 |

Note: Totals do not add due to rounding.

For the estimation of health benefits, the analysis focused on reductions in mortality risk due to the decreases in daily driving time and thus possible increases in sleep. For this analysis, we used low, medium, and high baseline levels of sleep to analyze the impacts of changes in hours worked on expected mortality risk to obtain a range of possible health impacts from changes in hours worked. Results of this analysis indicate that the measurable health benefits of reducing the maximum hours of work allowed per week could well be as great as the costs, and other possible health benefits (which have not been included in the quantitative analysis) could add even further to these benefits. The health benefits of Options 2 through 4 were estimated for three different levels of baseline sleep by drivers (shown in Exhibit ES-5). For the assumption of a high level of baseline sleep for Options 2 and 4, it is interesting to note that the benefits are negative (to a relatively minor extent for Option 2), indicating that it is not beneficial for individuals to get additional sleep if they are already getting adequate sleep.

Exhibit ES-5. Annual Health Benefits for Options 2 through 4
(Millions 2008$)

| Assumed Baseline Amount of Nightly Sleep | Total Benefits Due to Increased Sleep | | |
|---|---|---|---|
| | Option 2 | Option 3 | Option 4 |
| Benefits with Low Sleep | $1,480 | $1,190 | $1,990 |
| Benefits with Medium Sleep | $690 | $650 | $660 |
| Benefits with High Sleep | -$110 | $100 | -$670 |

Net benefits (i.e., benefits minus costs) are likely to be positive, but could range from a negative $750 million per year to more than a positive $1.4 billion per year for Option 2, from a negative $190 million to more than a positive $1.2 billion for Option 3, and from a negative $2.3 billion to more than a positive $1.3 billion for Option 4, as shown in Exhibits ES-6 through ES-8. The wide ranges in estimates of benefits and net benefits are a consequence of the difficulty of measuring fatigue and fatigue reductions, which are complex and often subjective concepts, in an industry with diverse participants and diverse operational patterns. Still, it seems clear that the benefits could easily be substantial, and are on the same scale as the costs. The costs, for their part, are large in absolute terms but minor when compared to the size of the industry: $1 billion per year (the total annualized cost for Option 2) is only half of 1 percent of revenues, $500 million per year (the total annualized cost for Option 3) is only one quarter of 1 percent of revenues, and $2 billion per year (the total annualized cost for Option 4) is only 1 percent of revenues in the for-hire long-haul segment of the industry. These total annual costs are an even smaller fraction of revenues of the long-haul segment as a whole.

Exhibit ES-6. Annualized Net Benefits for Option 2 (Millions 2008$)

| Assumed Percent of Crashes Due to Fatigue | Assumed Amount of Nightly Sleep | | |
|---|---|---|---|
| | Low Sleep | Medium Sleep | High Sleep |
| 7 percent | $840 | $50 | -$750 |
| 13 percent | $1,170 | $380 | -$410 |
| 18 percent | $1,450 | $660 | -$140 |

Exhibit ES-7. Annualized Net Benefits for Option 3 (Millions 2008$)

| Assumed Percent of Crashes Due to Fatigue | Assumed Amount of Nightly Sleep | | |
|---|---|---|---|
| | Low Sleep | Medium Sleep | High Sleep |
| 7 percent | $900 | $360 | -$190 |
| 13 percent | $1,100 | $560 | $10 |
| 18 percent | $1,260 | $720 | $180 |

Exhibit ES-8. Annualized Net Benefits for Option 4 (Millions 2008$)

| Assumed Percent of Crashes Due to Fatigue | Assumed Amount of Nightly Sleep | | |
|---|---|---|---|
| | Low Sleep | Medium Sleep | High Sleep |
| 7 percent | $340 | -$990 | -$2,320 |
| 13 percent | $900 | -$420 | -$1,750 |
| 18 percent | $1,370 | $50 | -$1,280 |

Compared to the other two options that were analyzed, Option 2 would have roughly twice the costs of Option 3 (which allows 11 hours of daily driving), and less than half the cost of Option 4 (which allows 9). In keeping with their relative stringencies, Option 3 has lower, and Option 4 has higher, projected benefits than Option 2. Option 3's calculated net benefits appear likely to be somewhat higher than the net benefits of Option 2 under some assumptions about baseline conditions. Option 4's substantially larger costs, on the other hand, did not appear to be justified by its generally higher range of benefits.

This analysis was, of necessity, limited in scope to calculations of what FMCSA judged to be the most important effects of the most important provisions of the rule changes under consideration. One provision that was not explicitly modeled was the prohibition on driving if more than 7 hours have elapsed since an off-duty break of at least 30 minutes. We did not attempt to compute the costs or safety impacts of the occasional 16-hour driving window. Because the use of this provision is voluntary, carriers would want to use it only when they expect it to improve their productivity. We were also unable to account for all of the benefits of the 2-night requirement of the restart provision. The additional costs of this requirement have been included, along with health and safety benefits of the reduction in work hours. The main point of the provision, though, is to address the extra need for rest for drivers on a night schedule. Those circadian-related benefits could not be incorporated at the time this analysis was conducted.

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# 1. Background

This Regulatory Impact Analysis (RIA) provides an assessment of the costs and benefits of potential changes in Department of Transportation (DOT) Federal Motor Carrier Safety Administration (FMCSA) Hours of Service (HOS) regulations. The HOS regulations address the number of hours that a commercial motor vehicle (CMV) driver may drive, and the number of hours a CMV driver may be on duty before rest is required, as well as the minimum amount of time that must be reserved for rest and the total number of hours to be on duty and the rest period at the end of a "work-week."

The HOS regulations in effect until 2003 were promulgated pursuant to the Motor Carrier Act of 1935 and codified at 49 CFR Part 395. These regulations were originally promulgated in 1937, and last revised significantly in 1962. They required eight hours off between tours of duty that could be of indeterminate length, lasting until the driver accumulated 15 hours on duty. They also limited work to 60 hours in a 7-day period or 70 hours in an 8-day period. Concerns that these regulations were outdated and contributed to driver fatigue led to an effort to incorporate new knowledge about fatigue, rest, and their effects on safety.

*The 2003 Revised Rule*

Revisions to the HOS regulations were proposed in a Notice of Proposed Rulemaking (NPRM) published in the May 2, 2000, Federal Register (65 FR 25540). Following reviews of the comments on the NPRM and additional study, FMCSA developed a revised set of HOS regulations. The final rule (the "2003 HOS rule") was promulgated on April 28, 2003 (68 FR 22456), and took effect on January 4, 2004. An RIA comparing the costs, benefits, and impacts of this rule relative to the previous rule and several alternatives was conducted in accordance with the requirements of Executive Order 12866. That RIA, which is available in the HOS rule docket [FMCSA (2002a)],[1] showed that full compliance with the 2003 HOS rule could both save lives and increase productivity compared to full compliance with the rule then in existence. Much of the safety advantage of the 2003 HOS rule was shown to come from the mandate for at least 10 hours off for each tour of duty, and from helping to keep drivers on a regular 24-hour cycle. The contributions to productivity of the new regulations came from a provision allowing drivers to "restart" the accumulation of their 60 or 70 hours on duty within 7 or 8 days once they took 34 hours off at one stretch.

*The 2004 Appeals Court Action*

After the 2003 HOS rule had been in effect for several months, it was vacated by a Federal appellate court. The United States (U.S.) Court of Appeals for the District of Columbia (D.C.) Circuit held, on July 16, 2004, that FMCSA had not considered effects of the changes in the HOS rule on drivers' health. Public Citizen *et al*. v. FMCSA, 374 F.3d 1209. Additionally, the Court expressed concerns about several areas of the rule, including:

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[1] For a list of the references cited in this RIA, see section 8—References, beginning on page 8-1.

- Permission to drive 11 hours in a tour of duty, rather than 10;
- Allowing more hours on duty in a given week as a result of the restart provisions;
- Allowing drivers to split their off-duty periods into two parts through the use of sleeper berths (that is, bunks within the tractor); and
- Lack of consideration of the use of electronic on-board recorders.

In response to the Court's action, Congress extended the 2003 HOS rule for a year, to give FMCSA a chance to revisit the issues cited by the Court [FMCSA (2003)]. A new HOS rule was published on August 25, 2005, retaining most of the provisions of the 2003 rule but requiring drivers using sleeper berths to spend 8 consecutive hours in the berth and take an additional 2 hours either off duty or in the sleeper berth; this 2-hour period must be counted against the 14-hour on-duty limit (70 FR 49978). The 2005 HOS rule also provided relief to some short-haul operations using lighter trucks [FMCSA (2005a)].

*The 2007 Appeals Court Action*

Public Citizen and others challenged the August 2005 rule on several grounds. On July 24, 2007, the D.C. Circuit ruled in favor of Public Citizen and vacated the 11-hour driving time and 34-hour restart provisions (Owner-Operator Independent Drivers Association. Inc. v. FMCSA, 494 F.3d 188 (D.C. Cir. 2007)). The Court concluded that FMCSA had violated the Administrative Procedure Act's (APA's) requirements by failing to provide an opportunity for public comment on the methodology of the Agency's operator-fatigue model, which FMCSA had used to assess the costs and benefits of alternative changes to the 2005 HOS rule. In particular, the Court found that the Agency had not adequately disclosed and made available for review the modifications it had made to the 2003 operator-fatigue model to account for time-on-task (TOT) effects in the 2005 analysis. The Court concluded that FMCSA's methodology had not remained constant from 2003 to 2005 because the TOT element in the model was new and constituted the Agency's response to a defect in its previous methodology. The Court concluded that the Agency violated the APA because it failed to give interested parties an opportunity to comment on the methodology of the crash risk model that the Agency used to justify an increase in the maximum number of daily and weekly hours that CMV drivers may drive and work. The Court listed several elements of the way FMCSA calculated the impact of TOT that it held could not have been anticipated and that were not disclosed in time for public comment upon them.

The Court also found, turning to Public Citizen's second argument, that FMCSA had failed to provide an adequate explanation for certain critical elements in the model's methodology. In vacating the increase in the daily driving limit from 10 to 11 hours, the Court found arbitrary and capricious what it described as FMCSA's "complete lack of explanation for an important step in the Agency's analysis," the manner in which it had plotted crash risk as a function of TOT per hours of driving. The Court also found that FMCSA had failed to provide an explanation for its method for calculating risk relative to average driving hours in determining its estimate of the increased risk of driving in the 11$^{th}$ hour. In vacating the 34-hour restart provision, the Court found that FMCSA also had provided no explanation for the failure of its operator-fatigue model to account for cumulative fatigue due to the increased weekly driving and working hours permitted by the 34-hour restart provision.

In an order filed on September 28, 2007, the Court granted in part FMCSA's motion for a stay of the mandate. The Court directed that issuance of the mandate be withheld until December 27, 2007.

On December 17, 2007, FMCSA published an Interim Final Rule (IFR) amending the Federal Motor Carrier Safety Regulations, effective December 27, 2007, to allow CMV drivers up to 11 hours of driving time within a 14-hour, non-extendable window from the start of the workday, following 10 consecutive hours off duty (72 FR 71247). The IFR also allowed motor carriers and drivers to restart calculations of the weekly on-duty time limits after the driver has at least 34 consecutive hours off duty. FMCSA explained that the IFR reinstating the 11-hour limit and the 34-hour restart was necessary to prevent disruption to enforcement and compliance with the HOS rule when the Court's stay expired, and would ensure that a familiar and uniform set of national rules governed motor carrier transportation. Public Citizen immediately requested the D.C Circuit to invalidate the IFR. However, on January 23, 2008, the Court issued a *per curium* order denying Public Citizen's request. On November 19, 2008, FMCSA adopted the provisions of the IFR as a final rule (73 FR 69567).

*2008 Petition and Settlement Agreement*

On December 18, 2008, Advocates for Highway and Automotive Safety, Public Citizen, the International Brotherhood of Teamsters, and the Truck Safety Coalitions (hereafter referred to as "HOS petitioners") petitioned FMCSA to reconsider the research and crash data justifying the 11-hour driving rule and the 34-hour restart provision. FMCSA denied the petition. On March 9, 2009, the HOS petitioners filed a petition for review of the 2008 rule in the D.C. Circuit and, on August 27, 2009, filed their opening brief. However, in October 2009, DOT, FMCSA, and the HOS petitioners reached a settlement agreement. DOT and FMCSA agreed to submit a new HOS NPRM to the Office of Management and Budget by July 26, 2010, and to publish a final rule by July 26, 2011. The parties filed a joint motion to hold the 2009 lawsuit in abeyance pending publication of the NPRM; the court later accepted that motion.

FMCSA proposes revisions to the HOS regulations promulgated in the Agency's 2008 HOS rule. The HOS regulations apply to motor carriers (operators of CMVs) and CMV drivers, and regulate the number of hours that CMV drivers may drive, and the number of hours that CMV drivers may remain on duty, before a period of rest is required. The current regulations are divided into "daily" and "multi-day" provisions, which can be expressed as follows:

- Drivers may drive up to 11 hours following an off-duty period of at least 10 consecutive hours.
- Drivers may not drive after the end of the 14th hour after coming on duty following an off-duty period of at least 10 consecutive hours.
- A driver may obtain the equivalent of 10 consecutive hours off duty if he has a period of at least 8 hours in the sleeper berth and a second period of at least 2 hours either off duty or in the sleeper berth. Compliance is calculated from the end of the first two periods.
- Drivers may not be on duty for more than 60 hours in 7 days (if the carrier operates only 6 days a week) or 70 hours in 8 days (if the carrier operates 7 days a week).

- Any period of 7 or 8 consecutive days can begin following a period of at least 34 consecutive hours off duty.

Several categories of motor carriers and drivers are exempt from parts of the HOS regulations or from the entire HOS regulation under the National Highway System (NHS) Designation Act of 1995 (referred to as the NHS Act).

## 1.1. PURPOSE AND NEED FOR REGULATORY ACTION

The purpose of the HOS limits is to reduce the likelihood of driver fatigue and fatigue-related crashes. Although the rules that existed prior to 2003 allowed less daily driving than the 2003, 2005, and 2008 rules (10 hours versus 11 hours), the driving could occur 15 hours or more after the driver started working, without any intervening rest, and followed a shorter minimum rest period (8 hours versus 10 hours). The change to a 14-hour consecutive duty period and a 10-hour, rather than an 8-hour, rest period was intended to limit the period in which a driver could operate a CMV and move the driver toward working a schedule that was consistent with the 24-hour circadian clock that humans function on normally. The 2008 rule does not limit the number of hours a driver can perform work other than driving, but if a driver works after 14 hours, he or she must take at least 10 hours off after finishing work before driving a CMV again. The change to a 10-hour off-duty requirement also recognized that drivers need to do other things in their off-duty time besides sleeping; the 10-hour break gives them an opportunity to obtain the 7–8 hours of sleep most people need to be rested and to carry out other necessary day-to-day activities. The 34-hour restart provision was intended to provide drivers with an opportunity to obtain two 8-hour rest periods, which research indicates can overcome cumulative sleep deprivation. Similarly, the sleeper berth provisions in the 2005 and 2008 rules eliminated the practice of splitting time in the sleeper berth into increments that were too short to provide a reasonable period of sleep.

One disadvantage of the restart provision is that it allows drivers to accumulate a substantially larger total number of on-duty and driving time in a 7-day period than the pre-2003 HOS rule allowed. The restart provision, combined with allowing 14 hours on duty per day and 11 hours of driving, enables drivers to accumulate 84 hours of on-duty time in a 7-day period, as opposed to the 60 hours allowed under the previous rule. Under the old rule, drivers could be on duty a maximum of 60 hours in 7 days or 70 hours in 8 days. The restart provision in the current rule allows them to re-set their weekly on-duty allowance after taking 34 consecutive hours off duty. Thus, if a driver maximized daily on-duty time for 5 days, he would reach his 70-hour limit of on-duty time, with 40 hours of off-duty time, for a total elapsed time of 110 hours. A 7-day week contains a total of 168 hours, so after taking 34 hours off duty to reset weekly on-duty time, the driver could then work another 14 hours before taking a final 10-hour off-duty period to end the week, thereby accumulating 84 hours on duty in 7 days. Although few drivers use the rule to these extremes, the potential for drivers to work these extended hours has been a main objection voiced by critics of the current HOS rule.

In addition, although 34 hours would enable a day-time driver to obtain two full nights rest with an intervening off day, the same cannot be said for night-time drivers. Night-time drivers generally flip their schedules on weekends – going from sleeping during the day and driving at night to sleeping at night and being awake during the day. As a result of flipping schedules, many night-time drivers would only get one period of consolidated sleep during a 34-hour restart rather than two periods of consolidated sleep. As a result, 34 hours may be inadequate to allow drivers on night schedules to overcome the sleep debt they are likely to have incurred during the work-week; daytime sleep is generally shorter than nighttime sleep and is more likely to be interrupted. The Agency is concerned that the increase in total maximum allowable work per week allowed by the rule, and the short restart, may result in adverse impacts on driver health and public safety.

## 1.2. OPTIONS

This analysis considers and assesses the consequences of four potential regulatory options. Option 1 is to retain the 2008 rule, while Options 2, 3, and 4 are to adopt several revisions to that rule. The options and the rationale behind their provisions are described briefly in this section. Based on the estimated net benefits of Options 2 through 4 relative to the no-action alternative of retaining the 2008 rule (Option 1), FMCSA is co-proposing Options 2 and 3.

### *1.2.1. Option 1*

Option 1 is to retain the 2008 HOS rule. The existing exemptions to the current HOS regulations under the NHS Act would remain in effect.

The 2008 HOS rule is divided into daily and multi-day provisions, which can be defined as follows:

- Following 10 consecutive hours off duty, operators can drive up to 11 hours within a period of 14 consecutive hours from the start of the duty tour.
- Short-haul operators of vehicles less than 26,001 lbs. gross vehicle weight/gross vehicle weight rating (GVW/GVWR), remaining within a 150-mile radius of their base, may keep timecards in lieu of logbooks and may be on duty up to 16 consecutive hours for 2 days during a 7-day work week.
- Operators cannot drive after being on duty up to 60 hours over the last 7 days or 70 hours over the last 8 days.
- If a sleeper berth is used, the equivalent of the normal 10-hour off-duty break is an 8-hour period in the sleeper berth and an additional 2-hour period either in the sleeper berth or off duty; provided that the duty periods preceding and following each of these two periods sum to no more than 14 hours.
- Operators who obtain 34 consecutive hours of off-duty time can begin a new period of 60 hours in 7 days or 70 hours in 8 days (i.e., the 7- or 8-day "clock" is restarted by a 34-hour off-duty period).

### *1.2.2. Option 2*

This Option differs from Option 1 as follows:

- Following 10 consecutive hours off duty, operators are limited to 10 (rather than 11) hours of driving within a period of 14 consecutive hours from the start of the duty tour.

- Operators may be on duty for only 13 hours within the 14-hour driving window.
- Twice a week, operators may extend the driving window to 16 hours. The extension of the driving window does not increase the 13-hour on-duty time. Thus, operators using an extension must take at least three hours off duty.
- Operators may not drive if more than seven hours have elapsed since the driver's last off-duty or sleeper-berth period of at least 30 minutes.
- The 34-hour restart must include at least two periods between midnight and 6:00 a.m. A driver may begin another 34-hour restart no sooner than 168 hours (7 days) after the beginning of the last restart. The driver must designate whether any period of 34 hours off duty is to be considered a restart.

### *1.2.3. Option 3*

Option 3 differs from Option 2 only in the amount of driving allowed within a duty period. Option 3 allows 11 hours of driving, or 1 hour more than Option 2.

### *1.2.4. Option 4*

Option 4 differs from Option 2 only in the amount of driving allowed within a duty period. Option 4 allows only 9 hours of driving, or 1 hour less than Option 2.

## 1.3. BASELINE FOR THE ANALYSIS

This RIA compares the annualized costs and benefits (in 2008 dollars) of Options 2 through 4 relative to the 2008 rule (i.e., Option 1),[2] and assumes that there is full compliance with each of the options. This approach ensures that the analysis captures the full effects of the options' provisions on costs and benefits. To examine the degree to which this assumption may differ from actual practice, FMCSA examined CMV roadside inspection data from 2004, the first full year the main provision of the current HOS rules were in effect, through 2009, the last complete year of data, to assess changes in carrier compliance with the HOS rules, focusing on those violations severe enough to warrant out of service (OOS) orders. Exhibit 1-1 shows the overall HOS OOS violation rates and the most prevalent types of individual violations (the OOS rate will be less than the sum of the individual categories because an inspection can result in multiple OOS violations). From 2004 to 2009, the overall OOS rate declined to about 84 percent of the initial level. OOS rates for the 11-hour driving limit declined to 67 percent, and OOS violations related to missing, incomplete, improper, or fraudulent "records of duty status" (RODS) declined to 84 percent of initial levels. Although there are not enough years of data to determine whether the declines in the HOS OOS violation rates in 2008 and 2009 are permanent, so far, incomplete inspection data for 2010 are showing further declines in the HOS OOS rate compared to that in 2009. These data represent the Agency's best estimate of the current state of HOS compliance; and, although there may be some uncertainty as to whether they are the most robust assessment

[2] Please refer to Appendix C of the RIA for a presentation of the present value costs and benefits of Options 2 through 4 for a 10-year analysis period, using 3 and 7 percent discount rates.

of baseline non-compliance with the HOS rules, projections of future non-compliance rates would be difficult to construct and would have high degrees of forecast uncertainty.

As can be seen from Exhibit 1-1, noncompliance rates, as measured by roadside inspection data, vary fairly significantly from year to year. It is also likely that roadside inspections identify noncompliance less than perfectly. As a result, it is difficult to project compliance rates for any HOS rule based on data available to the Agency. In any case, assuming less than full compliance with the new rule would cut the estimates of both costs and benefits proportionally, so while assuming some rate of non-compliance would affect total costs and total benefits, it would not affect whether any particular scenario had a positive or negative net benefit. In addition, the rank order of the various scenarios from highest to lowest net benefit would not change as a result of incorporating some level of noncompliance into the analysis. We therefore present the full compliance case to capture the full potential costs and benefits of the proposed rule.

Exhibit 1-1. 2004 – 2009 HOS OOS Violation Rates

| Violation Rate Category | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Ratio of 2009 to 2004 Levels |
|---|---|---|---|---|---|---|---|
| Total HOS OOS Violation Rate | 4.6% | 4.7% | 5.3% | 4.9% | 4.4% | 3.9% | 84% |
| Over 11 Hours Driving | 1.4% | 1.4% | 1.4% | 1.2% | 1.1% | 0.9% | 67% |
| Over 14 Hours On Duty | 1.3% | 1.3% | 2.1% | 1.9% | 1.7% | 1.5% | 118% |
| Over 60 Hours/7 Days or 70 Hours/8 Days | 0.4% | 0.4% | 0.4% | 0.4% | 0.3% | 0.3% | 62% |
| Missing, Incomplete, Improper, or Fraudulent RODS | 3.9% | 4.2% | 4.4% | 4.1% | 3.7% | 3.3% | 84% |

## 1.4. SUMMARY OF PREVIOUS ANALYSIS

The previous analysis included in the 2008 "Regulatory Impact Analysis for Hours of Service Options" [FMCSA (2008b)] assessed the potential consequences of two regulatory options. The first Option was to readopt the 2005 HOS rule, which allowed up to 11 hours of driving, allowed a new 7- or 8-day period to begin after a 34-hour restart break, and allowed some splitting of off-duty periods using sleeper berth periods of at least 8 hours supplemented by a 2-hour break that could be outside the sleeper berth. The second Option was more stringent, and allowed up to 10 (rather than 11) hours of driving and eliminated the restart provision. The second Option retained the sleeper berth provisions from the first option. Both options retained the provision in the 2005 rule allowing short-haul operators to use timecards instead of logbooks and to be on duty for up to 16 hours twice during a 7-day period.

The cost analysis divided the industry into broad segments and used a model to simulate carrier operations under different conditions and proposed HOS rules. The model calculated changes in miles driven under the different options. The analysis used that output as a measure of the change in productivity under each option.

The analysis measured the safety impacts of HOS options using an operator fatigue model to estimate changes in crash risks. The analysis multiplied the change in fatigue-coded crash risk by the value of affected crashes to estimate the total benefit of the rule.

The analysis determined that the more stringent option would cause a substantial productivity loss relative to readopting the 2005 rule. Industry-wide, the analysis estimated that productivity would decrease by 7.3 percent under the more stringent option, yielding an annual negative productivity impact of $2.4 billion (in 2005$). The analysis determined that the more stringent rule would reduce crash risks by 0.63 percent, yielding a savings of about $214 million (in 2005$) per year. The analysis estimated that the more stringent rule would have a net annual cost of $2.2 billion (in 2005$).

## 1.5. Overview of the Analysis

This RIA estimates the costs and benefits of proposed changes to the HOS rule (Options 2 through 4) by estimating the incremental costs and benefits of these options compared to the baseline of the current HOS rule (Option 1). Costs of the regulatory options arise due to the operational changes that drivers must make to comply with the new HOS rule provisions. This RIA estimates these costs by determining the losses in productivity that result from the regulatory options for categories of drivers working schedules of varying lengths. These changes in productivity are monetized using a factor estimated for the 2008 RIA [FMCSA (2008b)] which places a dollar value on each 1 percent loss in industry productivity.

Benefits of the regulatory options result from changes in driver safety (i.e., reduction in fatigue-related crashes) and improvements in driver health. Safety benefits are estimated by determining the reduction in driver fatigue levels which result from reductions in daily driving time and in weekly work time. These changes are then monetized using the estimated cost of all long-haul crashes as a basis for valuing the redistribution of 11$^{th}$ hour driving for Option 2 and of 10$^{th}$ and 11$^{th}$ hour driving for Option 4 to other drivers and to other driving days for the drivers whose schedules are truncated. Health benefits of the regulatory options are projected by estimating the potential reductions in mortality risk which result from decreasing work hours and thus potentially increasing sleep for drivers working intense schedules. Reductions in mortality risk are monetized through application of the concept of a VSL and the value of a statistical life year (VSLY). In addition, although not monetized, reductions in long working hours should result in improvements in health for drivers, resulting in lower health care costs and quality of life improvements. The drivers working schedules that approach the limits of the current rules would experience some income loss, because their working hours would be reduced, however; but work, and the associated income, would be transferred to other drivers.

## 1.6. Remaining Sections of the Report

Following this introduction and background, Chapter 2 of this report presents a profile of the affected industry. Following the industry profile are chapters which describe the methodology behind the calculation of the costs and benefits of the regulatory options. Chapter 3 describes the methodology for estimating the costs of operational changes. Chapter 4 describes the methodology for estimating the safety benefits of the regulatory options, and Chapter 5 describes the methodology for estimating the health benefits of the regulatory options. Next, Chapter 6 presents the results of the cost-benefit analysis of the regulatory options. Appendix A presents some additional information on the profile of the affected industry. Appendix B presents a literature review that was conducted on the effect of long work hours and poor sleep on poor health outcomes and mortality risk. Appendix C presents the costs, benefits and net benefits of individual components the HOS Rule under different assumptions of the baseline fatigue level. Appendix C also presents an analysis of the safety benefits of the HOS rule under different assumptions of the effectiveness of the rule for preventing fatigue-related crashes. Finally, Appendix D presents more details of the calculations of costs, safety benefits, and health benefits.

# 2. Industry Profile

The industry profile is presented in two parts. The first part concerns the size and structure of the trucking industry, including aspects such as revenue, output, and size of firms. The second part describes the industry's operating behavior: hours driven per day, duty hours per day and per week and other measures of intensity of effort relative to the amount of work permitted by the current rule.

Our concentration is on inter-city, as opposed to local, operations. In general, short-haul trucking work has far more in common with "ordinary" work than it does with long-haul trucking. Short-haul operations generally involve 5-day-a-week jobs, and much of the time on duty is given to tasks other than driving. Typical work days are roughly 8 to 10 hours and typical weeks are 45–55 hours. Many, if not most, of these drivers receive overtime pay past 8 hours in a day. Most of the work is regular in character; drivers basically go to the same places and do the same things every day. The rule changes now under consideration are expected to have little effect on such operations.

We need a clear definition of long-haul or over-the-road (OTR) service. Among industry participants and analysts these terms are sometimes used in different ways. Many carriers, for example, will distinguish between regional and long-haul service, the former being moves that can be done in a single day, the latter, moves that take more than a day. But this kind of regional service is definitely not local; it involves moves between cities that can be more than 400 miles and sometimes 500 miles apart.

Both for simplicity of presentation and because of the nature of the available data, we will use 100 miles as the point of demarcation between local and OTR service. Much of our information on working and driving hours is drawn from FMCSA's 2007 "Hours of Service Study," referred to as the "2007 FMCSA Field Survey" [FMCSA (2007b)]. Companies and drivers were identified as operating within or beyond a 100-mile radius. The Economic Census [U. S. Census Bureau (2007a)], which we used for data on revenue, defines a long-distance firm as one carrying goods between metropolitan areas; this is roughly compatible with a 100-mile radius for the distinction between local and OTR service. One hundred miles is also compatible with the length-of-haul classes in the 2007 Commodity Flow Survey (CFS) [Bureau of Transportation Statistics (Research and Innovative Technology Administration, DOT) & U.S. Census Bureau (2010)].

Much of our data is also drawn from FMCSA's 2005 "FMCSA Field Survey: Implementation and Use of the April 2003 Hours-of-Service Regulations," referred to as the "2005 FMCSA Field Survey" [FMCSA (2005b)], in which a local operation is one in which a driver returns to his or her home terminal at the end of every tour of duty. Under this definition, a driver could make one-way runs of at least 200 miles and still be recorded as in local service; this could be somewhat misleading. There is, however, good reason to believe that the great preponderance of the drivers identified as OTR in the 2005 FMCSA Field Survey and as beyond 100 miles in the 2007 FMCSA Field Survey are engaged in the same kind of operation. For this reason, and because of the other data sources, we are comfortable with the local/OTR distinction at 100 miles.

## 2.1 INDUSTRY SIZE AND STRUCTURE

The long-haul trucking industry is not homogeneous. Its various sectors are quite different from one another in their operating characteristics and, therefore, in the way in which they are affected by changes in HOS rule provisions. The principal sectors of the OTR industry are shown in Exhibit 2-1.

Exhibit 2-1. Principal Sectors of OTR Trucking Industry

| For-hire | | |
|---|---|---|
| Truckload | Less-than-truckload | **Private** |

The main line of division in OTR service is between private carriage of goods and for-hire carriage. Within for-hire carriage, there is another major division—between truckload (TL) and less-than-truckload (LTL) operation. There are major differences among the operating characteristics of private carriage and the two types of for-hire carriage, and these differences have important implications for the effects of changes in HOS rule provisions. TL carriers comprise the sector most affected by changes in the rule. Long-haul private carriers would also be affected, and there are some impacts on LTL services.

### *2.1.1. For-Hire vs. Private Carriage*

For-hire trucking firms are paid by others to haul goods. Virtually all of their revenue is derived from movement of freight or related services such as logistics management.

Private carriers are firms that manufacture or distribute goods and choose to carry their own goods. Generally, private carriers do this because they are very sensitive to requirements for timely and reliable service, either because of their own methods of supply-chain management or those of their customers. It is also the case for some private carriers that having their own drivers handle delivery to customers is part of their customer-relations effort.

There are major operational differences between private and for-hire carriage; as a consequence, HOS rule changes would have different effects on these sectors. A major factor is the regular and repetitive character of private carriage that sets it apart from a large part of for-hire service. Regularity, or its absence, in drivers' schedules makes a significant difference in the effects of HOS rule provisions. In general, regular operations would be less affected by the options under consideration.

### *2.1.2. TL vs. LTL Service*

The two principal forms of for-hire OTR service differ markedly from one another, both in the kind of service provided and in mode of operation. A TL firm moves a full truckload of freight, for a single shipper, directly from origin to destination. The driver goes to a facility of the shipper where the truck is loaded and drives to a destination point where the truck is unloaded. From there, he proceeds to another origin point to pick up another load and continues in the same manner.

An LTL company, by contrast, moves small shipments (typically in the range of 500 to 2,000 pounds) in a series of moves that involve both local and OTR operation. Local-service trucks pick up shipments from a number of shippers, bring them into terminals where they are consolidated into TLs for OTR moves to other terminals where the TL is broken down into the smaller individual shipments, which local-service trucks deliver to their final destinations.

### *2.1.3. OTR Revenue, Vehicle Miles Traveled, Tractors, and Drivers*

Estimating measures of size and output for the OTR sector presents some difficulty, because there are conflicting trends in different data series. Time series data from American Trucking Associations and the Federal Highway Administration (FHWA) show declining trends for OTR vehicle miles traveled (VMT). The CFS shows increasing ton-miles, and Economic Census data show increasing revenue (after adjustment for price increases).[3] We chose to base our estimates primarily on the revenue data reported by the Economic Census. This choice may be subject to question, but we believe the revenue data, adjusted for price increases, may be the more robust measure of activity and output.

For 2007, the Economic Census reports revenue of $180.158 billion for OTR for-hire carriage.[4] In 2007, approximate annual revenue from an OTR tractor was $175,000. We may use this figure to obtain the number of tractors. (Straight trucks are rarely used in OTR service.)

*180.158 billion ÷ 175,000 = 1,029,474 for-hire, OTR tractors*

We must increase the number of tractors to include private carriage. Tractors used in private carriage are 43.0 percent of tractors in for-hire service [FleetSeek (2008)]. We increase the number of tractors by 43.0 percent. (We assume the proportion of private tractors in OTR service is approximately the same as that in for-hire service.)

*1,029,474 x 1.43 = 1,472,148 OTR tractors*

We apply an industry average of 1.1 drivers per tractor [FMCSA (2007c)].

*1,472,148 x 1.1 = 1,619,363 OTR drivers.*

For the remainder of the analysis, this estimate of the number of drivers has been rounded to 1,600,000.

For total OTR VMT, we use an industry standard of approximately 100,000 miles per tractor per year. This leads to 147.2 billion VMT for OTR carriage. We estimate that LTL service accounts for approximately 17.0 percent of for-hire OTR VMT.[5] Exhibits 2-2 and 2-3 summarize our estimates for tractors, drivers, revenue, and VMT.

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[3] Details of data sources and calculations in this section are in Appendix A.

[4] This amount does not include household goods or parcel service.

[5] This is based on Vehicle Inventory and Use Survey (VIUS) data and revenue data from the 1992, 1997, and 2002 Economic Census; see Appendix A.

Exhibit 2-2. OTR Tractors and Drivers (Millions)

| | Tractors | Drivers |
|---|---|---|
| For-hire | 1.03 | 1.13 |
| Private | 0.44 | 0.49 |
| **Total** | **1.47** | **1.62** |

Exhibit 2-3. OTR VMT and Revenue (Billions)

| | VMT | Revenue |
|---|---|---|
| Truckload | 85.5 | 142.5 |
| Less-than-truck-load | 17.5 | 37.7 |
| Total for-hire | 103.0 | 180.2 |
| Private | 44.2 | N/A |
| **Total** | **147.2** | **N/A** |

### *2.1.4. Size of Firms and Distribution of Revenue*

Regarding number and size of firms, the TL and LTL sectors are very different. While a few thousand LTL firms are listed in most directories, the business is dominated by five national firms and a fairly small number of regional firms. Capital requirements make a high barrier to entry even for regional operations. An LTL operation requires a network of terminals with a fleet of trucks for local pick-up and delivery attached to each terminal. These trucks are in addition to the tractor trailers that make the runs between terminals. A regional firm may need 20 or 30 terminals; national firms may have 300 or more terminals.

The TL sector, by contrast, is a good example of atomistic competition. Barriers to entry are very low; one only needs credit adequate for the purchase of a tractor and trailer. There are over 70,000 independent firms (not counting leased owner-operators), and a substantial share of TL revenue goes to middle-sized and smaller companies. This is seen in Exhibit 2-4 which shows distribution of revenue by fleet size [FMCSA (2002a)].

Exhibit 2-4. Truckload Firms by Revenue

| Number of Tractors | Percent of TL Revenue | Size Classes Combined |
|---|---|---|
| 1 to 5 | 8.9% | 20.1% |
| 6 to 24 | 11.2% | |
| 25 to 99 | 23.3% | 48.1% |
| 100 to 499 | 24.8% | |
| 500 and more | 31.9% | 31.9% |

We see that firms with 6 to 99 tractors have over one-third of industry revenue; small and middle-size firms are a robust component of this industry.

Exhibit 2-5 shows number of firms distributed across size classes.[6] It also shows that small and middle-size firms are a major element of the industry.

Exhibit 2-5. Number of Truckload Firms by Fleet Size

| Tractors | Companies | Percent |
|---|---|---|
| 1-5 | 53,517 | 70.0% |
| 6-10 | 9,177 | 12.0% |
| 11-20 | 5,899 | 7.7% |
| 21-40 | 3,770 | 4.9% |
| 41-75 | 2,008 | 2.6% |
| 76-150 | 1,119 | 1.5% |
| 151-500 | 719 | 0.9% |
| >500 | 220 | 0.3% |
| **Total** | **76,429** | **100.0%** |

### *2.1.5. Local VMT*

In the 2003 RIA we estimated, for 2000, 80.0 billion VMT for local carriage, private and for-hire [FMCSA (2002a)]. To update this estimate to 2007, we have used the Gross Domestic Product (GDP) in 2000 and 2007 for a scaling factor. The result is an estimate of 94.5 billion local VMT in 2007.

## 2.2. OPERATING PATTERNS

To analyze the impact of rule changes, we need to know the prevailing operating patterns in the industry. Of particular interest is the degree of intensity of drivers' work. In other words, we are interested in the degree to which they work close to the limits set by the current rule. To analyze current patterns in work intensity, we assigned drivers to four intensity groups, based on their average weekly hours of work. For this purpose, we used data on weekly work hours from the 2007 FMCSA Field Survey to define intensity groups as shown in Exhibit 2-6.

Exhibit 2-6. Driver Groups by Intensity of Schedule

| Driver Group | Average Weekly Work Time | Percent of Workforce | Weighted Average Hours per Week |
|---|---|---|---|
| Moderate | 45 | 66% | 29.70 |
| High | 60 | 19% | 11.40 |
| Very High | 70 | 10% | 7.00 |
| Extreme | 80 | 5% | 4.00 |
| | | | **Total: 52.10** |

Moderate intensity drivers are on duty an average of 45 hours per week. High intensity drivers are on duty an average of 60 hours per week. The third group, very high intensity drivers, works

[6] Details of data sources and calculations are in Appendix A.

an average of 70 hours per week. The fourth group, extreme-intensity drivers, is on duty an average of 80 hours per week. We used data from the 2007 FMCSA Field Survey to distribute the driver population across these groups as shown above in Exhibit 2-6.

The weighted average is obtained by multiplying the average work time in each class by the fraction of the workforce in that class. The sum, just over 52 hours, is the average hours of work per week based on each group's share of the total population. Data analyzed in 2005 from the 2005 FMCSA Field Survey and a large TL carrier suggested a slightly higher industry-wide average work week of 53 hours, which is consistent with 52 hours used in the cost-benefit analysis.[7]

Exhibit 2-7 shows how the weekly work hours for the four intensity groups might break down in terms of days of work per week, hours of work per day, and driving hours per day. Previous analyses (based largely on the 2005 FMCSA Field Survey) showed average days of work per week falling between 5 and 6. Because longer work weeks are naturally associated with more intense schedules, we have assumed that the moderate intensity group typically works 5 days and that the others typically work 6. Those assumptions, combined with the average weekly work hours imply the average work hours per day shown in the exhibit. On the basis of the assumed average work hours per day, and data from the 2005 FMCSA Field Survey showing that driving hours are about 80 percent of work hours, we developed the typical driving hours per work day shown in the exhibit.[8] Finally, the Exhibit shows the breakdown of all daily tours of duty by driver group, based on the breakdown of the workforce shown in Exhibit 2-6 and the tours of duty per week shown in Exhibit 2-7. The moderate group of drivers represents a somewhat smaller percentage of all tours of duty than their fraction of the workforce because they are assumed to work fewer tours per week than the other drivers.

Exhibit 2-7. Working and Driving Assumptions by Intensity of Schedule

| Driver Group | Average Weekly Work Time | Assumed Typical Work Days per Week | Assumed Average Work per Day | Assumed Typical Driving per Day | Estimated Breakdown of Daily Tours of Duty |
|---|---|---|---|---|---|
| Moderate | 45 | 5 | 9 | 7 | 61.8% |
| High | 60 | 6 | 10 | 8 | 21.3% |
| Very High | 70 | 6 | 11.7 | 9 | 11.2% |
| Extreme | 80 | 6 | 13.3 | 10 | 5.6% |

We are particularly concerned with the percentage of duty tours in which drivers work close to the current limits in the following ways:

- Working 14 or more hours in a day

[7] These data are shown in Exhibit 2-6 in the 2008 RIA [FMCSA (2008a)]. Details are in Appendix A.

[8] The data collected in the 2007 FMCSA Field Survey had a slightly different structure than that collected in 2005. As a result, we are unable to calculate driving hours as proportion of total on-duty time from the 2007 data, and hence continue to use the 2005 data as a source for that information.

- Using the 11th driving hour in a day
- Using the 10th and 11th driving hours in a day

We need to know both the percentage of tours in each group, and the way in which working close to the limit is distributed across the intensity groups. We use 14 working hours for an example of the process. From the 2005 FMCSA Field Survey, we know that 14 or more hours are used in about 9 percent of tours. So the averages for each intensity group, weighted by their contributions to tours of duty, should sum to about 9 percent. We use our judgment and knowledge of the industry to distribute the incidence of use across the four intensity classes. We see this in Exhibit 2-8. (The percentages in the column for assumed use need not sum to 100 percent; they are the percentages of each group's use of the 14th hour.)

Exhibit 2-8. Incidence of Working 14 or More Hours

| Work Intensity Group | Percent of Tours of Duty | Assumed use of ≥ 14 Hours | Weighted Average Use |
|---|---|---|---|
| Moderate | 61.8% | 2% | 1.2% |
| High | 21.3% | 7% | 1.5% |
| Very High | 11.2% | 25% | 2.8% |
| Extreme | 5.6% | 60% | 3.4% |
| | | | **Total: 8.9%** |

Exhibits 2-9 and 2-10 show the same process applied for use of the 11th driving hour and use of the 10th and 11th hours. As with use of 14 or more work hours, the total weighted averages were obtained from the 2005 FMCSA Field Survey. The 2005 FMCSA Field Survey was used as the basis for these breakdowns because it provided more information on the distribution of daily duty hours, and because a comparison of the 2005 and 2007 surveys showed no significant difference in the use of the 11th hour.

Exhibit 2-9. Incidence of Driving in the 11th Hour

| Work Intensity Group | Percent of Tours of Duty | Assumed use of 11th Hour | Weighted Average Use |
|---|---|---|---|
| Moderate | 61.8% | 10% | 6.2% |
| High | 21.3% | 25% | 5.3% |
| Very High | 11.2% | 50% | 5.6% |
| Extreme | 5.6% | 70% | 3.9% |
| | | | **Total: 21.1%** |

Note: Total does not add due to rounding.

Exhibit 2-10. Incidence of Driving in the 10th and 11th Hours

| Work Intensity Group | Percent of Tours of Duty | Assumed use of 10th and 11th Hours | Weighted Average Use |
|---|---|---|---|
| Moderate | 61.8% | 25% | 15.4% |
| High | 21.3% | 50% | 10.7% |
| Very High | 11.2% | 75% | 8.4% |
| Extreme | 5.6% | 90% | 5.1% |
| | | | **Total: 39.6%** |

# 3. Methodology for Estimating the Costs of Operational Changes

This chapter presents our methodology for estimating the impacts of the new HOS rule provisions. These impacts result from losses in productivity occurring when drivers change their schedules to comply with the new rule provisions. The productivity loss measured in this analysis is a direct cost to the industry. This loss in productivity is also a societal cost because we assume that industry would pass this cost on to consumers in the form of higher prices for goods. Impacts on consumers of increased freight transportation costs would be small for individual households even for a rule that imposed substantial costs because these costs would be spread over a wide range of goods, purchased by millions of households. Each billion dollars of increased costs, passed on to U.S. consumers in the 117.5 million households estimated for the year 2010 by the U.S. Bureau of the Census, would cost an average household less than $9 per year [U.S. Census Bureau (2010)].

This chapter first presents an overview of our methodological approach, and then presents a detailed description of the methodology for estimating the impacts of the new rule. We relied, to some extent, on methods used in previous Regulatory Evaluations related to the HOS rules promulgated by FMCSA over the past several years. For a full description of aspects of the methodology used here, please refer to these documents, which can be found in the rulemaking Docket.

## 3.1. Overview

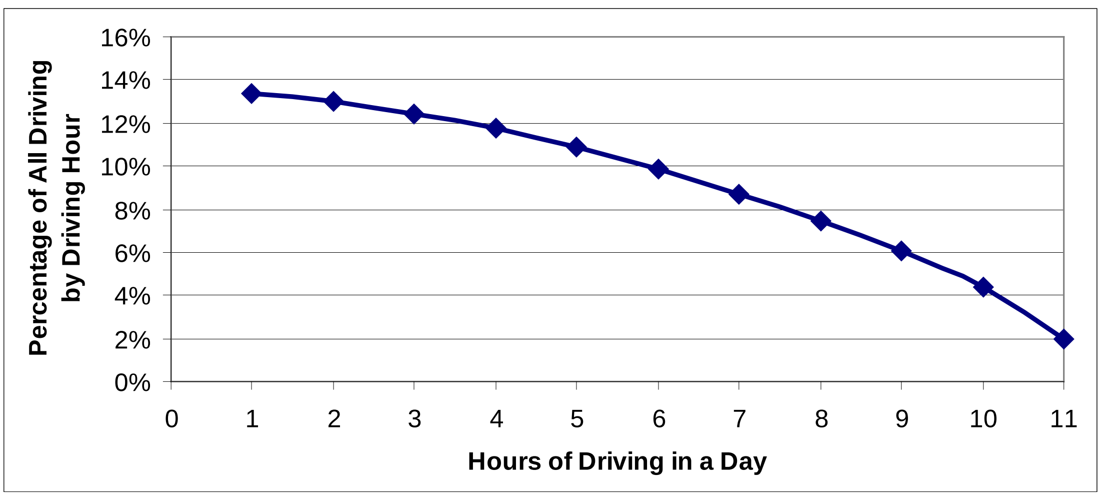
This chapter presents, in some detail, the methods used to estimate the costs of the proposed rule and the alternatives. Before going into detail, however, we present an overview of the approach to provide context for the individual analytical steps. Because the methodology for estimating the costs of operational changes is similar for Options 2 through 4, this chapter first presents details of the methodology for Option 2. Then, in section 3.3 we discuss how the methodology for estimating the costs of operational changes for Options 3 and 4 differs from the methodology for Option 2.

The basic approach for Option 2 is to follow the chain of consequences from changes in HOS provisions to the way they would impinge on existing work patterns in terms of work and driving hours per week, taking overlapping impacts of the rule provisions into account. The resulting predicted changes in work and driving hours are then translated into changes in productivity by comparing them to average hours. The changes in productivity, in turn, are translated into changes in costs measured in dollars using functions developed for the regulatory analyses of previous HOS rules.

Application of the new rule provisions to a widely varying population means we must look separately at the involved intensity groups. While past analyses divided the population into functional groups, ranges, and then into affected and unaffected categories, the need for simplicity and transparency in this accelerated rulemaking led to a division into four intensity categories. Because this rule makes rather marginal changes to the hours of work available for drivers working less than 70 hours per week, we have focused our analysis on the TL sector of the industry. In general, the changes being proposed in the accompanying NPRM were designed to impact only those drivers working the most intense schedules. As a result, the proposed changes would primarily impact the 15 percent of drivers who average 70 or more hours on-duty per week. Drivers who average less than 70 hours per week would not be affected by the new restart provision, and would be unlikely to approach the daily driving, on duty, or weekly on duty limits described in this proposal. While these drivers may approach 11 hours of driving, or 14 hours on-duty, on a particular day, they do so only occasionally. As a result, drivers working more moderate schedules are largely unaffected by the proposed changes. Generally speaking, TL sector drivers work longer hours and more intense schedules than other sectors of the industry, and, as a result, would be the sector most directly impacted by this rule. Data on industry-wide characteristics, combined with data from a limited number of consistent sources on overall intensity, and judgment on how the use of individual rule elements would impact driver schedules gave us a simplified picture of the work and driving characteristics of drivers with varying levels of intensity of work.

The basic approach to calculating the impact of changing the allowable hours of work per day, driving per day, and work per week is to model the existing distribution of these hours, and then estimate what is lost if that distribution is truncated at the upper end, so as to limit the extremes. For example, starting with a large data set on driving hours by long-haul drivers in individual days of driving from the 2005 FMCSA Field Survey (shown in Exhibit 3-1), we can array the hours of daily driving, and count the number of days that go beyond (in the case of Option 2) 10 hours (to 10.25, 10.5, 10.75, or 11 hours). We can then consider what would happen if no driver can go beyond 10 hours, summing up the number of hours lost for the trips that would have extended beyond 10 hours. For example, a trip that would have gone to 10.5 hours but now must stop at 10 hours loses half an hour. Dividing the total hours lost by the total hours driven gives the estimate of the average change in productivity.

**Exhibit 3-1. Percentage of All Long-Haul Driving by Hour, Based on 2005 FMCSA Field Survey**

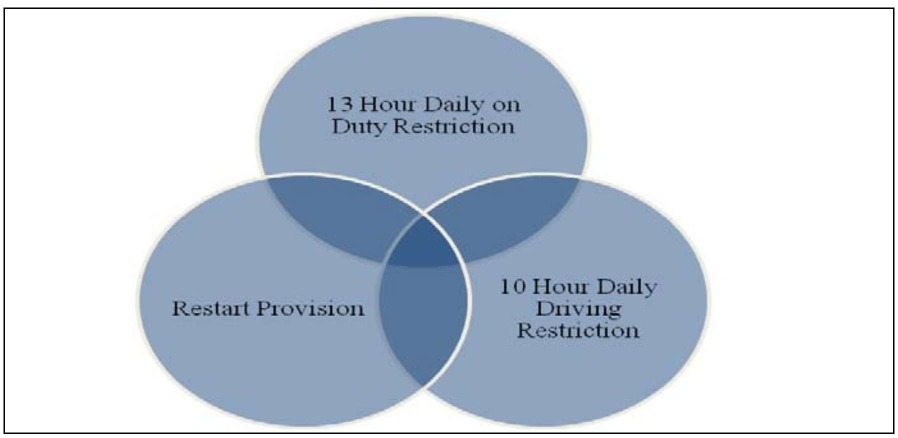



We can perform the same calculations for each of the important changes in the HOS rule provisions mandated by the options under consideration. The estimates of the total impacts of the proposal and the alternatives taken as complete packages, though, have to be more complex than the simple sum of the impacts of the individual provisions, because the provisions interact.

Drivers with the highest intensity schedules would be much more likely to lose productivity due to the changes in the restart. Any hours they lose due to the 10-hour driving limit, though, would not be lost again to the change in the restart, and counting both losses would be double-counting. Similarly, hours lost to the restriction to 13 hours cannot be re-lost to the 10-hour driving restriction or to the restart restrictions. To capture these effects realistically, we needed to examine drivers in different intensity groups individually.

As an example, consider the provision that restricts on-duty time to 13 hours. Since all driving time is on-duty time, eliminating an hour of on-duty time would reduce, to some extent, the hours a driver would drive in a given day. It is likely that the driver would be forced to reduce driving to some extent, but not by the full hour as the driver would reduce on-duty, not-driving time to some extent as well. However, because reducing total on-duty time to some extent restricts driving, it is less likely that a driver would hit the 11-hour limit, which would reduce the marginal impact on driving time due to reducing allowable driving from 11 to 10 hours for Option 2. The Venn diagram in Exhibit 3-2 below presents this idea graphically. The area of each circle represents the individual restrictions imposed by the various provisions of this rule. However, these effects interact because restrictions in one area make it less likely that drivers would be able to bump up against limits in another area, thus reducing the marginal impact of the other provisions. These interactive effects are represented by the area where the circles overlap. In order to avoid double or triple counting impacts, we must net out the overlapping sections that have already been accounted for in considering how other provisions affect total weekly work from the total impacts of the rule.

**Exhibit 3-2. Venn Diagram of Rule Provision Interactions for Option 2**




Data on the breakdown of long-haul drivers by average hours of work per week was taken from the 2007 FMCSA Field Survey. The distribution of hours of work per day was available only from the 2005 FMCSA Field Survey. That earlier survey was also used as a source for the distribution of hours of driving per day, though a cross-check showed close agreement between the 2005 and 2007 FMCSA Field Surveys in terms of daily driving.

To supplement the industry-wide data on work and driving hours, we made judgments about the way the more extreme hours of daily work and driving are distributed among drivers with higher and lower intensities of weekly work. For example, because it is impossible to build up 80 or more hours of work in a 7-day period without working a maximum daily schedule most of the time, we assumed that on more than half of work days, drivers working the longest weeks work and drive close to the legal maximum. We assumed the opposite was true for the drivers working the fewest hours per week. As described in Chapter 2, hours of driving and working per day were then assigned to the intermediate weekly work intensities so that the weighted average of long working and driving days aligned closely with the data on the industry-wide prevalence of long days.

Given a set of assumptions about baseline working and driving hours for drivers in different weekly intensity categories, we made judgments about the incremental effects of the changes in HOS provisions on the hours that drivers would be able to drive and work. These judgments, and how they determine the overall changes in productivity, are presented in detail in the sections below.

## 3.2. DETAILED EXPLANATION OF THE ESTIMATION OF CHANGES IN PRODUCTIVITY

The primary cost of the change in the HOS rule provisions is in the form of lost productivity which occurs when drivers have to change their driving schedules to comply with the new driving and working hour limits. This lost productivity would increase the cost of transportation services and ultimately increase the costs consumers pay for goods. To estimate the impact of these operational changes, we used the characterization of the driver population into four groups based on the intensity level of their weekly schedules, as discussed in Chapter 2. This breakdown of the driver population is shown in Exhibit 3-3.

Exhibit 3-3. Driver Groups by Intensity of Schedule

| Driver Work Intensity Group | Percent of Workforce | Total Number of Drivers | Average Weekly Work Time | Percent of Work Hours |
|---|---|---|---|---|
| Moderate | 66% | 1,056,120 | 45 hours | 57.0% |
| High | 19% | 304,000 | 60 hours | 21.9% |
| Very High | 10% | 160,000 | 70 hours | 13.4% |
| Extreme | 5% | 80,000 | 80 hours | 7.7% |

Exhibit 3-3 also shows how the total work effort is assumed to break down across intensity categories. Though the moderate intensity group constitutes 66 percent of all drivers, because they work less than the industry-wide average, their work amounts to a somewhat smaller percentage of all hours of work. The right-hand column of the table shows the breakdown of work implied by the breakdown of drivers and their assumed average weekly hours of work. The values were calculated by multiplying the percentage of all drivers falling into a category by the ratio of that category's average work hours per week to the industry-wide average hours per week. For example, the moderate group constitutes 66 percent of drivers, but their work effort is only 45 hours per week, compared to the industry-wide average of 52.1 hours. Multiplying 66 percent times the ratio of 45 to 52.1 yields 57 percent.

To estimate the impact of the change in operations for Option 2, we first subdivided the operational changes into three distinct effects: the effect of cutting working hours from 14 to 13 hours per day, the effect of cutting back maximum driving hours from 11 to 10 hours per day, and the effect of the new restart provisions. For the first effect, the effect of restricting daily work time, we have a reasonably solid estimate of the industry-wide use of the 14th hour from the 2005 FMCSA Field Survey. We used our judgment to allocate the total industry use of the 14th hour across the different categories of drivers. For example, use of the 14th work hour among the total industry is about 9 percent. We distributed the use of the 14th hour among the different categories of drivers so that the weighted average use (use of the 14th hour by each category multiplied by the percent that each category comprises of the total population) of the 14th hour equaled roughly 9 percent. The estimated use of the 14th hour across the different driver categories is shown below in Exhibit 3-4. As can be seen from Exhibit 3-4, the extreme intensity group uses the 14th hour on 60 percent of work days, on average. However, as presented in Chapter 2, less than 6 percent of work days are this long, and the drivers working these long hours perform less than 8 percent of the work hours. The partial impact of restricting on-duty time to 13 hours would be the percentage of time lost to the entire industry due to the cut-back these drivers would have to make in their on-duty time. A simplified example of this calculation would be to take the total time of lost work due to the reduction in on-duty time divided by the total hours the driver would work to find the impact on those drivers' productivity, and then multiplying this number by the percentage of the industry's output that these drivers contribute (in this case 7.7 percent). This calculation would yield the total percentage change in industry productivity that would result from the drivers working the most extreme schedules having to cut back to 13 hours of on-duty time per day.

Exhibit 3-4. Assignments of Daily Schedule Intensities Across Weekly Intensity Group

| Driver Group | Percent of Work Effort | Assumed Use of the 14th Hour of Work | Assumed Use of the 11th Driving Hour | Assumed Use of the 11th and 10th Driving Hour |
|---|---|---|---|---|
| Moderate | 57.0% | 2% | 10% | 25% |
| High | 21.9% | 7% | 25% | 50% |
| Very High | 13.4% | 25% | 50% | 75% |
| Extreme | 7.7% | 60% | 70% | 90% |

Further assumptions in how drivers would adjust their use of time given this restriction are needed to identify the total impact on the industry. These assumptions are described more fully below, but involve reasonable judgments about how drivers might re-allocate some of the time they lose on more intense days to less intense days if daily on-duty time is restricted to 13 hours. Even the drivers who work the most intense schedules do not push the daily on-duty time limits every day, which leaves them some room to increase work on these less-intense days. If daily on-duty time is restricted, they can therefore make up a portion of the time lost on their most intense days by working more intensely on another day that week. While this transfer of work to less intense days would lead to somewhat longer hours on these days, these drivers would still be bound by the 13 hour on duty limit. Even with slightly more work on a particular day, their level of fatigue would still be less on these shorter days than it would be on a day when they were working up to the current 14 hour limit. We have adjusted for the impact of this transfer of time on safety benefits by modeling crash risk reduction in a way that accounts for the fact that any intra-driver transfer of time would be added to the end of that driver's less intense days. The methodology for these adjustments is described in Section 4.2 below. We believe our assumptions about this re-allocation of time are reasonable. Similar adjustments are made for the other provisions of the proposed rule.

For the second effect of the operational changes resulting from Option 2, the reduction of driving hours from 11 to 10 per day, we used a similar procedure to estimate the use of the 11th hour by each driver category. From the 2005 FMCSA Field Survey, we know that industry-wide use of the 11th hour is at about 21 percent of daily tours of duty. We used our judgment to allocate use of the 11th hour across the driver categories so that the weighted average use (use of the 11th hour by each category multiplied by the percent that each category comprises of the total daily tours of duty) of the 11th hour equaled roughly 21 percent. The estimated use of the 11th hour across the different driver categories is shown in Exhibit 3-4.

The next step in estimating the impact of operational changes for Option 2 was to determine the incremental impact of each of the two effects on productivity discussed above. First, for the cutting back of daily on-duty hours from 14 to 13, we made judgments for each group of drivers on how they would adjust to the proposed rule. For example, for the high intensity group, we assumed that only half of an hour needs to be lost or shifted to another day because the driver is likely to take a break during the day. We assumed that this group would be able to shift half of this lost half hour to another day, but would lose the other half, for an expected loss of a quarter of an hour. To determine the resulting impact on productivity, we took the assumed number of trips that use the 14th hour and first divided it by two to reflect the fact that most of the days that used the 14th hour would not use the full hour (because even in a 14-hour day about half an hour would be an off-duty break). We then divided this number by two again to reflect the fact that half of this lost half hour could be shifted to another day. We then divided this number by the average number of hours worked per day for this group to determine the impact on productivity. The average number of hours worked per day for the high intensity group was assumed to be 10 hours, based on spreading the average weekly work hours of 60 over 6 work days. These calculations resulted in an incremental impact on productivity of 0.18 percent for the high intensity group (7% / 2 / 2 / 10 hours). We repeated this calculation for each of the driver categories, using our judgments of how each group of drivers would adjust their schedules to the new rule. Drivers with more intense schedules are assumed to lose a greater proportion of time, since they work closer to the daily and weekly limits on a regular basis and therefore have less room to shift any lost time to other days of the week. These productivity impacts were then weighted by each group's share of total industry output. The results of these calculations for all categories of drivers are shown below in Exhibit 3-5.

Exhibit 3-5. Productivity Impacts of Reducing Daily Work Time

| Driver Group | Percent of Work Effort | Unweighted Productivity Impact | Weighted Productivity Impact |
|---|---|---|---|
| Moderate | 57.0% | ~0% | ~0% |
| High | 21.9% | 0.18% | 0.038% |
| Very High | 13.4% | 1.07% | 0.144% |
| Extreme | 7.7% | 4.5% | 0.345% |

The next step was to weight the estimated productivity impact by multiplying the incremental impact by the percent of all drivers that are in each category of drivers. For the high intensity group, this resulted in a weighted incremental impact on productivity of 0.038 percent (0.18% x 21.9%). In other words, the impact on productivity caused by the restriction on daily work time to 13 hours by the high intensity group comes to 0.038 percent of total industry productivity. These calculations were repeated for the other groups of drivers, and the results are shown in Exhibit 3-5.

Similar calculations were then performed to estimate the incremental impact for Option 2 of cutting driving hours from 11 to 10 per day. First, we made assumptions for each group of drivers as to how they would reallocate their driving time to adjust to the new rule. For example, for the high intensity group, we assumed that 35 percent of the driving that would have occurred in the $11^{th}$ hour can be shifted to some other day. This leaves 0.65 hours on each day that they would have used the $11^{th}$ hour that is lost. To calculate the impact of this lost 0.65 hours on their productivity, we divided by the average number of hours this group drives per work day. As discussed in Chapter 2, we have assumed this group averages 8 hours of driving per day, based on their average work hours and an assumption that they spend 80 percent of an average day driving. For the high intensity group of drivers, this resulted in a total of 2.03 percent (25% x 0.65 / 8) of lost productivity. We performed similar calculations for the other driver groups, using our judgment of how each group would adjust their schedule to accommodate for the new rule. The resulting percentages of lost productivity for each driver group are shown below in Exhibit 3-6.

Then, similarly to above, we weighted this productivity impact by multiplying the incremental impact for each driver group by the percent of work hours performed by drivers in that category. For example, for the high intensity group, we multiplied the 2.03 percent of lost productivity by 21.9 percent (the percent of work effort contributed by this group) to obtain a weighted average productivity impact of 0.44 percent. We repeated this calculation for the other driver groups, and the resulting weighted productivity impacts are shown below in Exhibit 3-6.

Exhibit 3-6. Productivity Impacts of Reducing Daily Driving Time for Option 2

| Driver Group | Percent of Work Effort | Unweighted Productivity Impact | Weighted Productivity Impact (Without Double Counting Adjustment) | Weighted Productivity Impact (With Double Counting Adjustment) |
|---|---|---|---|---|
| Moderate | 57.0% | 0.79% | 0.45% | 0.45% |
| High | 21.9% | 2.03% | 0.44% | 0.43% |
| Very High | 13.4% | 4.17% | 0.56% | 0.49% |
| Extreme | 7.7% | 5.95% | 0.46% | 0.28% |

Lastly, to avoid double-counting this impact, we subtracted from this weighted impact the percent of the incremental impact of reducing daily work hours, much of which comes from driving. An examination of the days that exceeded 13 hours of work in the 2005 FMCSA Field Survey showed that driving hours exceeded 10 on about half of those days. Based on that finding, we assumed that 50 percent of the productivity lost due to the 13 hour work limit comes from driving. We thus subtract 50 percent times the estimated incremental impact of restricting daily work time (0.038%). These calculations resulted in a weighted incremental impact on productivity of just under 0.43 percent for the high intensity group (0.44% - (0.038% x 50%))

once the possible double-counting issue was accounted for. These calculations were repeated for the other groups of drivers, and the results are shown in Exhibit 3-6.

The final piece of determining the cost of operational changes for Option 2 was to estimate the impact of the new restart provision. A major impetus behind the restart provision is to allow drivers some flexibility and to reduce some of the negative productivity impacts of the new HOS rule provisions. The restart provision, which can be used once per week, enables drivers to reset their weekly driving limits if they take a break up to 34 hours in length which includes two periods from 11:00 PM to 7:00 AM. This provision has enough flexibility in it to let drivers get in close to 70 hours of work time per week. The restart provision helps reduce maximum work by day drivers by encouraging them to stop before accumulating the full 70 duty hours before a restart. Because this provision only impacts drivers who average more than 70 hours a week of work time, the moderate and high intensity driver groups are unaffected by this provision.

To estimate the impact of the restart provision on the very high and extreme intensity driver groups, it was necessary to first convert the impacts of the restrictions on daily work and driving time to the amount of hours lost per week per driver. To estimate the total hours lost due to the new HOS rule, we calculated the hours lost due to the restriction in daily working time and the restriction in daily driving time and summed the two effects to obtain the total hours lost. For the restriction in work time from 14 to 13 hours per day, we multiplied the expected number of hours per day that would be lost by each group by the number of days that group is expected to work in a week. For example, for the high intensity group, this calculation resulted in a total of 0.105 hours lost per week (7% / 4 x 6) due to the restriction of 13 hours of on-duty time per day. We performed similar calculations for the other groups of drivers.

Next, we calculated the hours lost due to the restriction in daily driving time to 10 hours. We calculated this by multiplying the expected number of hours per day that would be lost by each group by the number of days that group is expected to work in a week. For example, for the high intensity group, this calculation resulted in an average of 0.98 hours lost per week (25% x 0.65 x 6) before adjusting for the effects of the 13-hour restriction, and a slightly lower 0.93 hours after the adjustment, due to the restriction in driving hours to 10 hours per day. We performed similar calculations for the other driver groups.

Now that we had an estimate of the hours lost due to the restrictions on daily work and driving time, we could estimate the impact of the restart provision. The new restart provision does not affect drivers averaging 60 or fewer hours per week of work time, so there was no change due to this provision for the moderate and high intensity driver categories. Because these two groups are estimated to account for 85 percent of all drivers, none of the changes in the restart provision will affect more than the remaining 15 percent of drivers. Changes in the restart provisions fall into two categories: the requirement that all restarts include two complete periods between midnight and 6 a.m., and the requirement that drivers wait a full week between restarts. The 2-night restriction will significantly affect only a fraction of the drivers who work more than 60 hours per week because most of them drive during the day and would naturally either comply with the rule or need to make only minimal changes in their schedules. (Drivers who end a series of work days any time in the late afternoon or evening would be able to start again after 6 o'clock in the morning about a day and a half later, having taken two periods between midnight and 6 a.m. Drivers who would otherwise run until 1 or 2 a.m. would need to adjust by only 1 or

2 hours to stop by midnight, and so forth). Only drivers who regularly drive the entire night would lose a significant amount of time due to the 2-night restriction. FMCSA believes that some of the largest groups of regular night drivers already take full weekends off, the segment of the population experiencing significant impacts will be small. Data from the 2005 and 2007 FMCSA Field Surveys, on the distribution of start and end times and the lengths of restart breaks, reveal that no more than 38 percent of drivers' schedules impinge on the midnight-to-6 a.m. period, and only about 20 percent would need to be altered by more than 4 hours per restart to comply. Thus, no more than 20 percent of the 15 percent of drivers in the two most intense groups – that is 3 percent overall – would be seriously affected.

Using the data on start and end times discussed above, and assumptions about the drivers' most likely response to the need to take 2 full nights off, we calculated that the very high and extreme intensity groups of drivers would lose a weighted average of 0.7 work hours per week as a result of the 2-night restriction. For the very high intensity drivers, this loss of a weighted average of 0.7 hours would be the only significant impact on their use of the restart. For the extreme intensity group of drivers, the impact of the restart provision was determined by taking the average hours worked per week for this group (80) and subtracting the hours lost due to the restrictions in daily work time (3.60) and the hours lost due to the restriction in daily driving time (2.22) minus 70 hours, which is allowed under the new restart provisions. The loss of 0.7 hours per week due to the 2-night restriction in the restart provision was added to this number, to arrive at a total of 4.88 hours ((80 – 3.60 – 2.22 – 70) + 0.70) lost per week due to the new restart provision for the drivers with extremely intense schedules.

Similarly to how lost hours were converted to changes in productivity for the restrictions in daily work time and driving time, we next converted the lost hours due to the restart provisions to lost productivity. For the very high intensity drivers, the loss of 0.7 hours per week due to the restart provisions was divided by the average work hours per week for this group and then multiplied by the percent that this group comprises of total industry effort. This calculation resulted in a total of 0.134 percent (0.7 hours / 70 hours x 13.4%) of lost productivity for this group of drivers due to the restart provision. We performed a similar calculation for the drivers with extremely intense schedules.

The next step was to monetize the changes in productivity due to the rule provisions for Option 2. For this step, we used the estimated cost of a 1 percent change in productivity that was calculated in the 2008 HOS RIA. This value was estimated at $335 million (2005$) in the 2008 RIA. Inflating this value to 2008 dollars using the GDP inflation index and then adjusting for the slightly lower number of drivers assumed for this analysis (i.e., 1,600,000 as opposed to the 1,632,000 assumed for 2008) resulted in a total of $356 million for each 1 percent loss in productivity. We then multiplied the value of a 1 percent change in productivity by the total percentage changes in productivity estimated for each of the new rule provisions that affect productivity. For example, the sum of the productivity impact for the four categories of drivers due to the restriction in daily work hours from 14 to 13 was 0.53 percent (0 for moderate intensity drivers + 0.038% for high intensity drivers + 0.144% for very high intensity drivers + 0.345% for extremely intense drivers). Multiplying this 0.53 percent impact on productivity by the cost of $356 million per each 1 percent loss of productivity resulted in a total cost due to the restriction in daily work time of $188 million. (This cost estimate is shown in Exhibit 6-1, rounded to $190 million.) This calculation was then repeated for the restriction in daily driving time and the restart provision to obtain the total impact due to lost productivity from the new HOS rule provisions.

Next, the impacts of the different rule provisions for Option 2 were summed to estimate the total impact on changes in productivity for each group of drivers. For the high intensity group of drivers, this resulted in a total of 1.04 hours of productive time lost per week. This total resulted from the summation of 0.105 hours lost per week due to the restriction in daily work time from 14 to 13 hours, 0.93 hours lost per week due to the restriction in daily driving time from 11 to 10 hours, and no change in productivity as a result of the new restart provisions. Similar calculations were performed for the other groups of drivers to obtain the total productivity impacts for each category of drivers. We used the calculated changes in weekly work for the estimation of the safety benefits of the new HOS rule provisions, which is discussed in the next chapter.

## 3.3. Estimation of Costs of Operational Changes for Options 3 and 4

In this section, we discuss the changes to the methodology for estimating the operational costs of Option 2 for the estimation of the operational costs for Options 3 and 4. These options differ from Option 2 only in the amount of driving they allow within a duty period. Option 3 allows 11 hours of driving, or 1 hour more than Option 2. Option 4 allows only 9 hours of driving, or 1 hour less than Option 2.

The analyses for Options 3 and 4 are similar in approach to the analysis performed for Option 2, but several assumptions and intermediate calculations differ. Therefore, we discuss the two analyses in terms of how they differ from Option 2.

To estimate the impact of the change in operations, we first subdivided the operational changes into three distinct effects: the effect of cutting working hours from 14 to 13 hours per day, the effect of changes to the maximum driving hours allowed per day, and the effect of the new restart provisions. Option 3 allows the 11$^{th}$ hour of driving per day, so we do not account for those incremental impacts in the changes of operational patterns. Option 4, on the other hand, does not allow the 11$^{th}$ or the 10$^{th}$ hour of driving, so we accounted not only for the productivity impacts incurred by the cut to 10 hours, but also, for those incurred by the cut to 9 hours.

### *3.3.1 Methodology for Option 3*

Option 3 allows for the 11$^{th}$ hour of driving, so the impact on productivity results from the loss of 1 hour of duty time per day and the lost hours due to the new restart restriction. There are also impacts on safety that result from the loss of some fraction of the 11$^{th}$ hour of driving as a result of the lost 14$^{th}$ hour of work.

For the restriction in work time from 14 to 13 hours per day, we used the same assumptions for the amount of the hour that must be lost or shifted to another day as we used in Option 2. Next, we multiplied the expected number of hours per day that would be lost by each group by the number of days that the group is expected to work in a week. For example, for high intensity drivers, this calculation resulted in a total of 0.105 hours lost per week ((7% / 4) x 6) due to the restriction of 13 hours of on-duty time per day. We performed similar calculations for the other groups of drivers. These impact estimates match those calculated for Option 2.

To calculate the lost 11th hours per week due to the daily work time restriction, we multiplied the lost hours per week due to the daily work time restriction by the percent of the productivity lost due to the work limit that come from driving (50 percent). We then multiplied this product by the ratio of the baseline number of hours driven per day to the baseline hours worked per day. We repeated this calculation for all driver groups, and the resulting impacts are shown in Exhibit 3-7.

Exhibit 3-7. Lost 11th Hours Due to the 13-Hour Daily Work Time Restriction

| Driver Group | Lost 11th Hours |
|---|---|
| Moderate | 0.00 |
| High | 0.04 |
| Very High | 0.29 |
| Extreme | 1.35 |

An additional impact incurred under Option 3 is the impact of the new restart provision. Similar to Option 2, the new restart provision does not affect drivers averaging 60 or fewer hours per week of work time, so there was no change due to this provision for the moderate and high intensity driver categories. For the very high intensity group of drivers, the new restart provision was estimated to result in a loss of 0.7 hours per week due to the 2-night restriction in the restart provision (this is the same impact estimated for Option 2). For the extreme intensity group of drivers, the impact of the restart provision was determined by taking the average hours worked per week for this group (80) and subtracting the hours lost due to the restrictions in daily work time (3.60) and 70 hours, the latter of which is allowed under the new restart provisions. The loss of 0.7 hours per week due to the 2-night restriction in the restart provision was added to this number to arrive at a total of 7.10 hours ((80 – 3.60 – 70) + 0.70) lost per week due to the new restart provision for the drivers with extremely intense schedules.

Next, we converted the lost hours due to the restart provisions to lost productivity. For the very high intensity drivers, the lost productivity under Option 3 matches that under Option 2. For the drivers with extremely intense schedules, however, this calculation resulted in a total of 0.681 percent (7.1 hours / 80 hours x 7.7 %), which differs from the analogous estimate under Option 2.

### *3.3.2 Methodology for Option 4*

Option 4 does not allow for the 10th or 11th hours of driving so the impact on productivity results from the lost 10th and 11th hours of driving, the 13-hour restriction, and the lost hours due to the new restart restriction. We ignored the 13-hour limit because it would have almost no incremental effect beyond the 9-hour driving limit.

To calculate the incremental impact of the cut to 9 hours of driving, we assumed the following uses of the 10th and 11th hours of driving for the moderate, high, very high, and extreme categories: 25 percent, 50 percent, 75 percent, and 90 percent. In addition, we assumed that 1.5 hours from the 10th and 11th hours are either lost or shifted to another day, because reducing an 11-hour day to 9 hours is a loss of 2 hours, and reducing a 10-hour day to 9 hours is a loss of 1 hour, and 1.5 hours is the average of 2 hours and 1 hour. We assumed that the following fractions of those 1.5 hours can be shifted: 0.35 for moderate intensity driving schedules; 0.25 for high intensity driving schedules; 0.15 for very high intensity driving schedules, and 0.05 for extremely intense driving schedules. These fractions are smaller than for Option 2 because, with the tighter constraint on driving, it is less likely that driving can be increased on other days. We first multiplied the assumed use of the 10th and 11th hours by the hours that must be lost or shifted (1.5) and the fraction of those hours that can be shifted to other days. We then divided the resulting product by the expected number of hours of driving on a typical day to find the fraction of baseline driving that is lost, and multiplied that by the percent of total work effort contributed by the intensity category to find the weighted average impact on productivity. For example, the incremental impact of a cut to 9 hours for the very high intensity category was 1.43 percent (0.75 x 1.5 x (0.85 / 9) x 0.134). We performed similar calculations for each intensity category. The results of these calculations are presented in Exhibit 3-8.

Exhibit 3-8. Incremental Impact of the 9-Hour Driving Time Restriction

| Driver Group | Incremental Impact |
|---|---|
| Moderate | 1.99% |
| High | 1.54% |
| Very High | 1.43% |
| Extreme | 0.98% |

Similar to Options 2 and 3 above, the new restart provision does not affect drivers averaging 60 or fewer hours per week of work time, so there was no change due to this provision for the moderate and high intensity driver categories. For the very high intensity group of drivers, the new restart provision was estimated to result in a loss of 0.7 hours per week due to the 2-night restriction in the restart provision (as for the other options). For the extreme intensity group of drivers, we estimated the impact of the restart provision by taking the average hours worked per week (80) and subtracting the hours lost due to the restrictions in daily driving time (7.7) and 70 hours, the latter of which is allowed under the new restart provisions. The loss of 0.7 hours per week due to the 2-night restriction in the restart provision was added to this number, to arrive at a total of 3.01 hours ((80 – 7.7 – 70) + 0.70) lost per week due to the new restart provision for the drivers with extremely intense schedules.

We next converted the lost hours due to the restart provisions to lost productivity. For the very high intensity drivers, the impact is the same as in Option 2 and Option 3. For the drivers with extremely intense schedules, this calculation resulted in a total of 0.288 percent (3.01 hours / 80 hours x 7.7 %).

# 4. Methodology for Estimating Safety Benefits

This chapter presents our methodology for estimating the safety benefits of the new HOS rule provisions. These benefits result from reductions in fatigue risk due to the decreases in daily driving time and weekly work time. In this chapter, we first present an overview of our methodological approach, and then present a literature review on fatigue risk and TOT, and, finally, we present a detailed description of the methodology for estimating the safety benefits of the new rule. As mentioned above, ideally, the agency would have data to measure crash risk along all of the dimensions for which regulations are proposed. Because the agency has been not been able to gather such data, it has based its analysis, in significant part, on share of crashes that are fatigue-coded. The agency recognizes that using share of crashes that are fatigue-coded could have two possible problems: Accident inspectors may be more likely to code crashes as fatigue-related if the driver has been on the road longer. Also, the share of crashes that are coded as fatigue-related may conceivably increase simply because the share of crashes caused by other factors goes down. There could be no increase in the risk of a fatigue-related crash (the central question), but an increase in the share of fatigue-related crashes. The Agency has little evidence that either of these factors are a significant problem.

Nonetheless, while the data are not as complete as FMCSA would like them to be, the Agency aimed to limit, to the extent possible, the likelihood that drivers will be fatigued, either when they come on duty or during or at the end of a working period. Safety benefits are based on this reduction in fatigue and an associated reduction in fatigue-coded crashes.

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## 4.1. Overview

As with the previous section, this presentation of the methods used to estimate safety benefits begins with an overview of the approach before going into detail. Safety benefits are the monetized reductions in crashes that can be anticipated to follow from reductions in fatigue. In past regulatory analyses, the effects on fatigue, and fatigue-related crashes, of changing the HOS rule provisions were calculated using fatigue models. These models (the Walter Reed Sleep Performance Model for the 2003 rule [Balkin, T., *et al*. (2002)], and the closely related SAFTE/FAST Model for later analyses [Eddy, D.R., & Hursh, S.R. (2001)][9] took into account the drivers' recent sleeping and waking histories, and calculated fatigue based on circadian effects as well as acute and cumulative sleep deprivation. These models did not incorporate a function that independently accounted for long hours of driving in a single day (i.e., acute TOT), neither did they explicitly account for the effects of cumulative hours of work (as opposed to off-duty time) over several days. These effects were assumed, instead, to be accounted for in the effects of long daily and weekly work hours on the drivers' ability to sleep. For the 2005 and later analyses, a separate TOT function, based on statistical analysis of Trucks Involved in Fatal Accidents (TIFA) data [Matteson, A., *et al*. (2008)], was added to ensure that available evidence for TOT effects was not ignored; those analyses were still criticized as deficient for excluding consideration of cumulative TOT effects.

[9] Please visit www.fatiguescience.com for more information on the SAFTE/FAST Model.

For the current analyses, FMCSA is replacing the use of the sleep-related fatigue models with a simpler approach that explicitly incorporates fatigue related to hours of daily driving and hours of weekly work. The function used to model the effects of daily driving hours is the same as that used since 2005, while the function for modeling weekly work hours is taken from FMCSA's analysis of the Large Truck Crash Causation Study (LTCCS) [Toth, G., *et al*. (2006)]. Because both fatigue functions – for daily driving (TOT) and cumulative fatigue (weekly work hours) – used in the RIA were estimated independently without taking multiple factors into account, it is theoretically possible that each one incorporates some of the effect of the other. This circumstance could, then, lead to a measure of double-counting, if some of the apparent effect of long driving hours is actually due to long work hours in previous weeks, and vice versa. Our analysis of the data shows that, in this case, there is almost no correlation between the variables (because the 11$^{th}$ hours are spread across all categories of drivers). Because there is little correlation (with no statistical significance) between hours driven today and hours driven in the past week, the two functions operate independently of one another, and hence there should not be any concern about double-counting of benefits. Other fatigue effects, including the effects of insufficient sleep and the circadian effects of working and sleeping at sub-optimal times, are implicitly assumed to be incorporated in the daily driving and weekly work hour functions because those effects were at work on the drivers involved in the crashes recorded in TIFA and LTCCS. To add fatigue effects calculated by a sleep/performance model on top of the empirically based functions would, therefore, run the risk of double counting the benefits of restrictions on work and driving. These functions, and the uncertainty surrounding them, are described further in the following sections.

The basic approach for using the empirically based fatigue risk functions is to count the changes in hours worked and driven as a result of the regulatory options. Each hour of driving that is prevented results in a reduction in expected fatigue-related crashes. These reductions are calculated using the predicted levels of fatigue-coded crashes indicated by the fatigue functions. The hours of driving and working that are prevented by the options, though, are assumed to be shifted to other drivers or to other work days rather than being eliminated altogether. The fatigue crash risks for those other drivers and other days are also taken into account. Taking account of these partially offsetting risks means that that the predicted crash reductions attributable to the options are really the net effect of reducing risks at the extremes of driving and working while increasing risks for other drivers and on other days.

The changes in crash risks are monetized using a comprehensive and detailed measure of the average damages from large truck crashes. This measure takes into account the losses of life (based on DOT's accepted VSL, recently set at $6 million), medical costs for injuries of various levels of severity, pain and suffering, lost time due to the congestion effects of crashes, and property damage caused by the crashes themselves [Zaloshnja, E., & Miller, T. (2007)].[10]

[10] Average large truck crash costs were obtained from this report. The cost of a crash was updated to 2008 dollars and to reflect a value of a statistical life of $6 million.

## 4.2 LITERATURE REVIEW ON FATIGUE AND WORK

Workers experience a number of different types of fatigue while on the job. The three major types of fatigue affecting work performance are industrial, cumulative and circadian [Saccomanno, F.F., *et al*. (1995)]. These types of fatigue are described below, focusing on the literature relating to truck drivers.

Industrial fatigue results from working continuously over an extended period of time without proper rest, often referred to in the literature as fatigue resulting from TOT. For example, a truck driver who has been driving for 8 hours, without a break, might be subject to industrial fatigue. Some studies have shown performance to decrease as TOT increases [Dinges, D.F. & Kribbs, N.B. (1991)]. TOT problems could be exacerbated by sleep loss, even in the early stages of the task. One study concluded that for sleep-deprived individuals, performance is compromised even at early stages of performance of a monotonous task if the situation is undemanding and boring. This study suggested that the effect of sleepiness becomes immediately evident in the form of reduced vigilance [Gillberg, M. & Akerstedt, T. (1998)].[11]

Cumulative fatigue arises from working for too many days on any protracted, repetitive task without any prolonged break. This fatigue results from a lack of alertness brought on by familiarity and boredom with the task at hand. A truck driver could experience cumulative fatigue, for example, under the current HOS rules, after working for 14 hours, taking 10 hours off and then working another 14 hours (working a total of 28 hours in a 38 hour period).

Circadian fatigue is a function of the circadian rhythm. Fatigue is greatest when approaching or at the nadir of the circadian cycle, where the body is least vigilant. The truck accident rate is much higher during the early morning hours than during any other time of day, supporting the circadian effect hypothesis that accidents are more likely to occur when the human body is least vigilant [Harris, W. (1978)].[12]

Night and rotating shift workers are especially susceptible to being fatigued on the job [Akerstedt, T. (1988); Mitler, M.M., *et al.* (1988); Gold, D.R., *et al*. (1992)]. Permanently assigned graveyard-shift workers sleep between 5.8 to 6.4 hours per day [Bonnet, M.H. & Arand, D.L. (1995)]. Rotating shift workers, such as many truck drivers, sleep even less when they work a night shift (5.25 to 5.5 hours). Shift workers experience disturbances in their circadian rhythm, as measured by changes in hormonal levels [Akerstedt, T. & Levi, L. (1978)]. They are also less alert during nighttime shifts and perform less well on reasoning and non-stimulating tasks than non-shift workers [Akerstedt, T. (1988); Akerstedt, T., *et al*. (1981)]. Though nightshift work for many workers is regular (i.e., the same schedule is kept over time), truck drivers often have irregular schedules which can amplify the effects of circadian, cumulative, and industrial fatigue and increase the risk of fatigue-related accidents.

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[11] "Vigilance" was measured through a 34-minute visual vigilance test.

[12] See previous section entitled "The Biology of Sleep" for further discussion of the circadian effect.

### *4.2.1 Fatigue and Truck-involved Accidents*

Fatigue increases over the duration of trips, regardless of the driving schedule [Williamson, A.M., *et al*. (1996)]; and total driving time has a significant effect on crash risk, though there is variation on the point at which crash risk increases significantly, depending on the study methodology [Lin, T.D., *et al*. (1994); Frith, W.J. (1994)]. A study of industrial fatigue in truck drivers found that, in over 65 percent of cases, truck accidents took place during the second half of a trip, regardless of trip length [Mackie, R.R. & Miller, J.C. (1980)]. An analysis of Bureau of Motor Carrier Safety data in the 1970s found that about twice as many accidents occurred during the second half of trips than during the first half, regardless of trip duration [Harris, W. (1978)]. Another study found that the risk of accident increased after the fourth hour of driving and peaked after 9 hours of driving [Kaneko, T. & Jovanis, P. (1992)]. These studies are among many finding that industrial fatigue plays a role in predisposing truck drivers to accidents.

Determining the magnitude of this effect, however, and ensuring that other factors (such as sleep history and time of day) have been factored out, is quite difficult. Ideally, perhaps, we would want to compare the number of serious crashes in the each hour of driving after an extended break to the total driving time by hour of driving or, alternatively, vehicle miles traveled by hour. Conceptually, the degree to which the distribution of crashes falls into later driving hours relative to the distribution of driving would indicate the change in risk for longer trips. The data set would have to be reasonably representative of the drivers affected by the regulations; large enough to provide an accurate picture for individual hours, despite the rarity and randomness of crashes and the relatively small fraction of driving in the later hours; use an unbiased measure of hours; and cover a period in which long driving hours were legal. Furthermore, data on other factors that are known to affect fatigue and crash risks – total time on duty that day and previous days, short breaks, opportunities for restorative rest, time of day, and experience, for example – would have to be included in the data set as well, to allow the TOT effect to be isolated.

A data set meeting these criteria is not available at this time. There are some large samples of crash data that include the number of hours of driving, including the LTCCS and TIFA; but the time periods these cover are largely or entirely before the HOS rules were changed in 2003. They are also deficient, to varying degrees, in the availability and reliability of information on driver schedules and other factors that affect crash risks. Even more seriously, these studies do not directly provide information on the distribution of all driving by hour for either the drivers involved in the crashes or for comparable drivers. In other words, the data sets provide the numerator for the rate of crashes per hour, but not the denominator.

It is possible to develop distributions of all driving by hour (through surveys, for example), but these cannot be used along with crash data for a different population without biasing the results to an unacceptable degree. Researchers have also collected data on both crashes and total driving hours for the same populations; but, to date, these studies have had samples too small (and narrow, in terms of their subjects' characteristics) to give reliable results on long hours. FMCSA is currently sponsoring a study based on schedule data collected by electronic logs that should be able to solve most of the problems in this type of research, but that study is not complete as of the time of this analysis.

Researchers have long asked how long a person can sustain work effort at different tasks without lengthy breaks, before his or her performance of those tasks becomes unacceptably degraded. There has always been a notion that, by itself, sustained performance at a task (TOT) eventually results in a "fatiguing effect," manifesting itself in the form of slower response times or errors of omission or vigilance. Below is a short literature review of five studies about the TOT effect on driving and some concluding remarks.

Jones, I.S., and Stein, H.S. (1987) attempted to provide "adjusted odds ratios" to different categories of "length of time in driving" (TOT), assigning a baseline value of 1.0 to the relative risk of the likelihood of crashes attributable to a driving time from 0 to 2 hours; and they presented an increased odds ratio of 1.2 for driving times from 2 to 5 hours and also 5 to 8 hours of driving time (TOT). The odds ratio for driving more than 8 hours was estimated at 1.7, but the work of Jones and Stein said nothing about projecting odds ratios for driving more than 9, 10, or 11 hours relative to driving more than 8, the root question of the entire discussion of truck driver HOS.

Lin, T.D., *et al*. (1993) introduced a time-dependent logistic regression model formulated to assess the safety of motor carrier operations. They described their model as being flexible, allowing the inclusion of time-independent covariates, time main effects, and time-related interactions. The model estimated the probability of having a crash at time interval t, subject to surviving (not having a crash) before that time interval. Covariates tested in the model in this paper included consecutive driving time, multiday driving pattern over a 7-day period, driver age and experience, and hours off duty before the trip of interest. Although the work of Lin, T.D., *et al*. (1993) has some appeal in the conduct of our study, their methods and modeling are of some concern in that they do not model beyond the 8-9 hours of driving incidents, something which is obviously needed to examine the HOS alternatives.

In their description of nine logistic regression modeling attempts, Lin, T.D., *et al*. (1993) stated that driving time (TOT) has the strongest direct effect on accident risk. The first 4 hours consistently have the lowest crash risk and are indistinguishable from each other. Accident (crash) risk increases significantly after the fourth hour of driving, by approximately 50 percent or more, until the seventh hour. The eighth and ninth hours show a further increase, approximately 80 percent and 130 percent higher than the first 4 hours. In a follow-on extension of the study conducted by Lin, T.D., *et al*. (1993), Park, S.W., *et al.* (2005) conducted a detailed analysis of preexisting crash and non-crash data representing an estimated 16 million vehicle miles of travel, which identified a persistent finding of increased crash risk associated with hours driving, with risk increases of 30 percent to more than 80 percent in later hours compared with the first hour of driving. These increases are somewhat more muted than the effects found in related earlier studies, such as Lin, T.D., *et al*. (1993), but provide further evidence that crash risk is higher in later hours of driving.

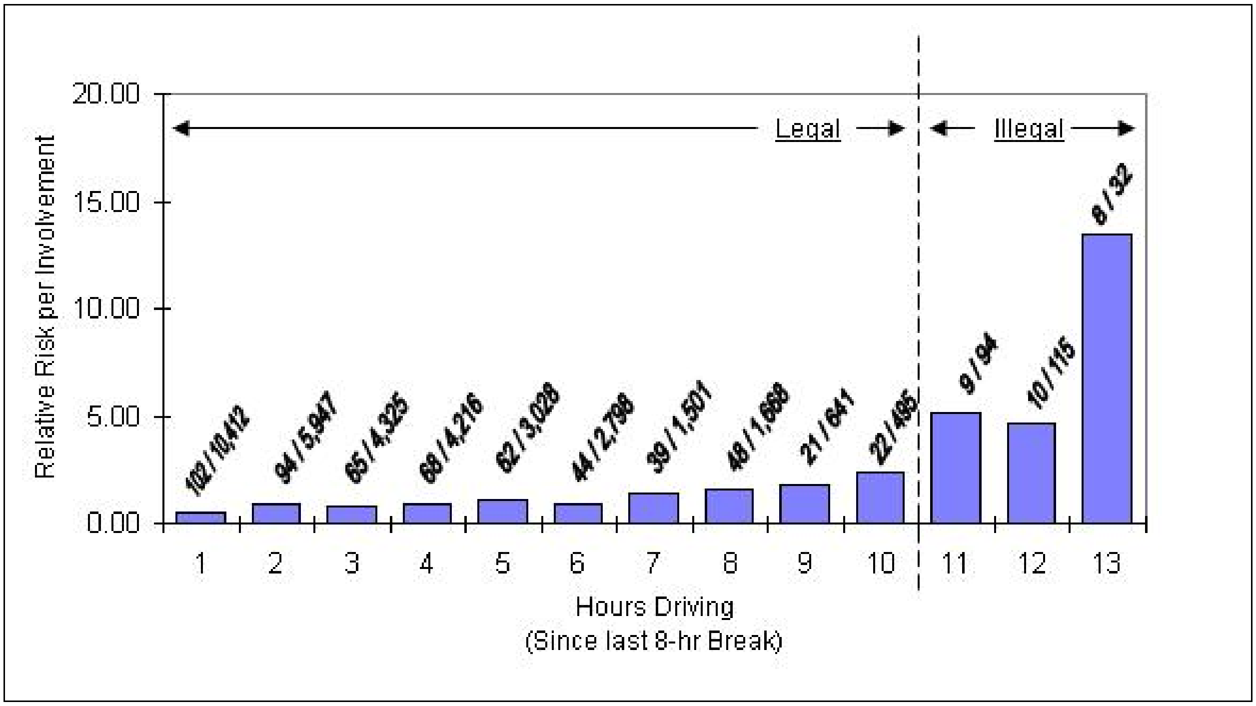
Campbell, K.L. (1988) stated that there is a steady increase in the probability of accident involvement with the number of hours driving. To look into this, Campbell used data from accident reports filed with the Office of Motor Carriers and extracted the time of day that the accident occurred, the number of hours driving at the time of the accident, and the intended driving period had the accident not occurred. The accidents that were coded as the driver having dozed at the time of the accident were used to determine the TOT effect. The problem arises since not all of the crash data were included; crashes may have been caused by fatigue, yet the driver was not dozing at the time. It was concluded that the crossover point in which the proportion of accidents in the latter hours of driving is more frequent occurs around four hours of driving.

O'Neill, T.R., *et al*. (1999) studied the operating practices of CMV drivers, as well as the relationship of these practices to driver fatigue. Drivers worked a 14-hour on/10 hour off schedule, driving a simulator for a 5-day week. Two 30-minute breaks and a 45-minute lunch break were taken during the day at regularly scheduled times. The observed recovery effect of the breaks was rather striking. The effects of 6.5 hours of driving were virtually reduced to the starting levels by a 45-minute break [O'Neil, T.R., *et al*. (1999)]. It is important to keep in mind that, while this recovery effect is remarkable, it occurred under very strict, adhered-to conditions. This effect took place under daytime driving conditions, the 14 hours on/10 hours off driving schedule that allowed for adequate rest, and scheduled breaks. It cannot be said with a reasonable degree of certainty that this recovery effect would occur in the same way under different conditions.

The analysis of TOT effects presented below in the safety analysis relies primarily on similar methodology to that used in two more recent research efforts, one by Ken Campbell and one by a team led by Dr. Paul Jovanis at Pennsylvania State University [Campbell, K.L. (2005); Jovanis, P.P., *et al*. (2005)]. Both efforts were undertaken specifically for FMCSA.

The Campbell analysis used national level data from the TIFA database for the years 1991-2002, comprising over 50,000 truck-involved crashes [Campbell, K.L. (2005)]. This database was developed from truck crashes in the National Highway Traffic Safety Administration (NHTSA) Fatality Analysis Reporting System (FARS) database, with additional data on the driver and the carrier involved, compiled by the University of Michigan Transportation Research Institute (UMTRI) after FARS data are published. Most importantly, UMTRI added data on time since the driver's last 8-hour break, the truck and carrier types, and the planned trip length to the FARS data to create the TIFA database. Note that, because this data collection effort predates the 2003 rule change, the results reflect pre-2003 HOS regulations: driving time for interstate operations was limited to 10 hours, the minimum rest time between trips was only 8 hours, and there were no provisions for a restart of the cumulative 7/8 day duty period. Much of the driving after the 10$^{th}$ hour was by drivers who were breaking the law since it was illegal before 2003 for drivers engaged in interstate commerce to drive more than 10 hours in a work shift. These drivers' behavior might be expected to be generally riskier than those who follow the rules. However, the methodology used by this study controls for this effect. This study looked at fatigue-coded crashes as a share of all crashes that occurred in each hour. The denominator – all crashes that occurred during the 11$^{th}$ hour – should suffer from this same risky driver effect as fatigue-coded crashes - and the effect should cancel itself out when looking at the relative proportion of fatigue-coded crashes during illegal hours of driving. Also, States have been allowed by 49 CFR 350.341(e)(1) to permit up to 12 hours of driving within a 16-hour window for drivers engaged in intrastate commerce, and some chose to do so. Since TIFA is a census of fatal crashes, and some fatal crashes involve drivers engaged in intrastate commerce, a portion of the 11$^{th}$ and 12$^{th}$ hour crashes occurred within legal intrastate commerce driving limits. The Campbell analysis addressed several aspects of the effect of driver fatigue on crash risk, including the fraction of crashes where fatigue was reported as the leading cause in FARS, the prevalence of fatigue by motor carrier industry segment, truck type, time of day, and hours of driving at the time of the crash. For the last of these analyses, a chart was provided of relative crash risk for each successive hour of driving. Relative crash risk for each hour is calculated as a multiple of the crash risk in the first hour. Exhibit 4-1 shows the results.

Exhibit 4-1. Relative Risk of Fatigue Involvement – TIFA

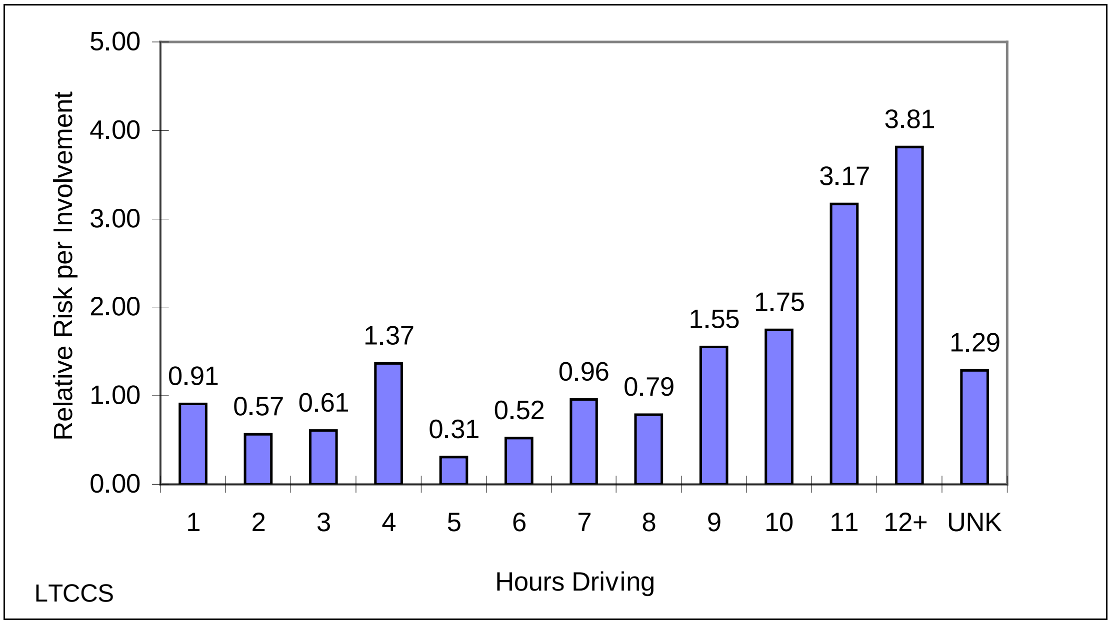



NOTE: Numbers above each bar chart represent the number of large trucks involved in fatigue crashes and total fatal crashes, respectively.

Data Source: Trucks Involved in Fatal Accidents (TIFA), 1991-2002.

For example, for the 10th hour of driving, Exhibit 4-1 indicates that the relative risk per involvement in a fatigue-coded crash is roughly 2.5 times higher than in the first hour of driving (reading across to the vertical axis of the chart). In the 11th hour of driving, the relative risk per involvement in a fatigue-coded crash is roughly five times higher than that in the first hour. The first number above each bar chart represents the number of large trucks involved in *fatigue-coded fatal* crashes between 1991 and 2002 for each driving hour, while the second represents the total number of large trucks involved in *all fatal* crashes within that same driving hour. For example, within the 11th hour of driving, there were 9 large trucks involved in fatigue-coded fatal crashes between 1991 and 2002, while there were 94 large trucks involved in all fatal crashes during that same driving hour. The figures above each chart help to provide a better understanding of the prevalence of large truck fatal crashes in each driving hour, in that they reveal that as driving hours increase, the number of fatal crashes, as well as fatigue-coded fatal crashes, generally decrease in a steady fashion.

**Exhibit 4-2. Relative Crash Risk by Driving Time – LTCCS Data**

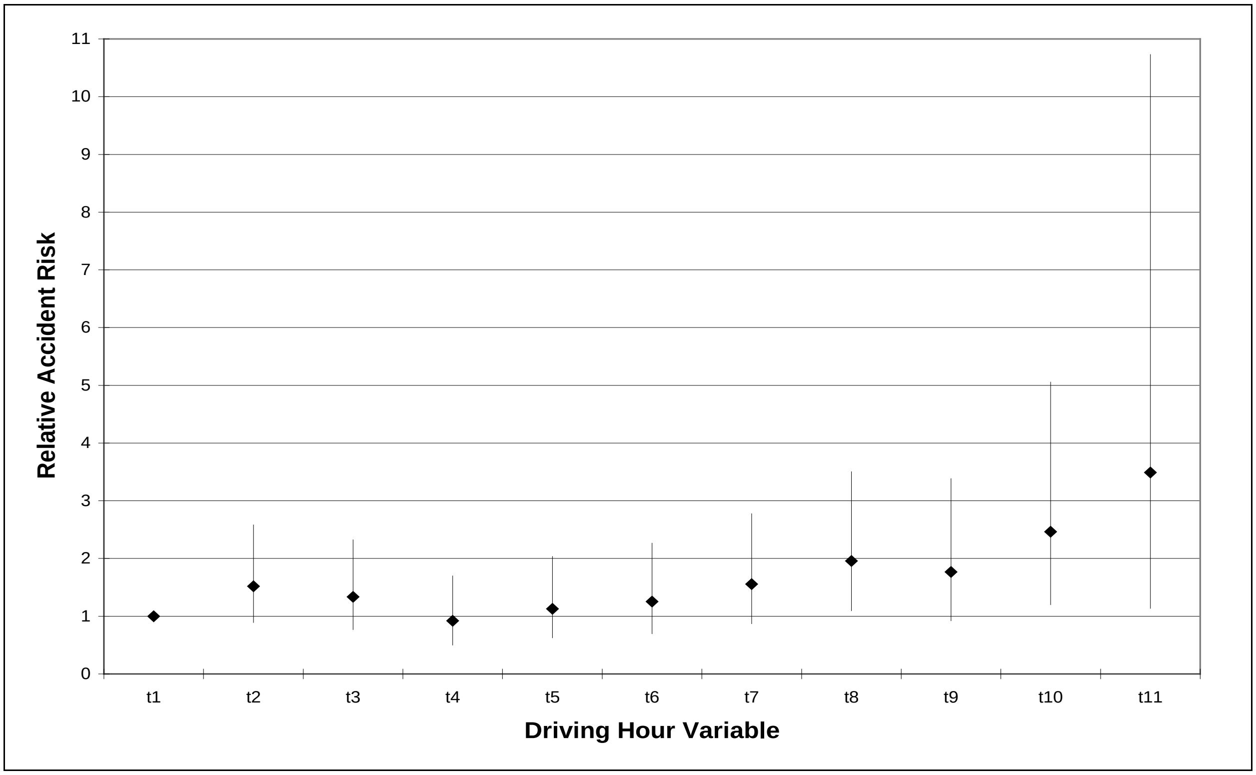



Campbell followed this analysis with a similar analysis of data from the LTCCS [Campbell, K.L. (2005)]. These data covered the period April 1, 2001 to December 31, 2003 and contain a sample of nearly 1,000 crashes. The result of the driving time analysis is shown in Exhibit 4-2 above. The overall result is similar to that derived from the TIFA data, although relative fatigue involvement factors for hours exceeding 10 hours represented by the LTCCS data appear to be lower than from TIFA data. The preliminary LTCCS data include injury crashes as well as fatal crashes, and it is not clear whether the relative risk data includes the injury crashes.

In contrast to the Campbell analysis, the Penn State/Dr. Paul Jovanis analysis relied on a sample of logbook data obtained from three cooperating LTL carriers, as described in the report to FMCSA [Jovanis, P.P., *et al*. (2005)]. The sample included 7-day driver records for 231 crashes and comparable data for 462 similar periods without a crash. The sample periods were randomly selected. All the data obtained were calendar year 2004, after the introduction of the revised HOS regulations which permitted an 11$^{th}$ driving hour and required longer breaks between on duty periods. The sample of commercial operators driving in the 11$^{th}$ hour was very small, with the data limited to 34 drivers. TOT task effects were calculated for the entire sample and for different subsets of the data, including operations with team drivers and sleeper berths, and different start times and shift patterns.

The result for all industry segments and driving routines combined is shown in the following Exhibit 4-3. The main limitation with this analysis is that it is representative of only one trucking industry segment (LTL carriers). Additionally, there are very few driver cases involving 11 hours of driving (34, which includes both crash and non-crash cases), which is presumably causing the very high variance surrounding the estimated 11$^{th}$ hour crash risk. The data show an 11th hour risk factor of about 3.4, which would be substantially higher than the equivalent estimates derived from the Campbell - LTCCS data discussed above because it refers to all crashes rather than to fatigue crashes only. Jovanis also reported that the results are comparable to results obtained from a similar analysis of data gathered in the 1980s [Park, S.W., *et. al*., (2005)].

**Exhibit 4-3. Relative Crash Risk With Driving Time (Jovanis Sample of LTL Operation)**




### *4.2.2 Naturalistic Driving Study*

Finally, the Agency also sponsored a naturalistic driving study conducted by Hanowski, R.J., *et al.* (2009). This study, peer reviewed and published, is important because unlike some other studies of the effects of driving hours on crashes, this study is able to directly measure the risk by hours of driving. This study involved outfitting trucks with monitoring equipment and then examining the data on critical incidents and crashes to determine, among other things, whether the number of safety critical incidents — defined here as crashes, near crash events, or crash relevant conflicts — increases with increased hours of driving in a given day. This study, which resulted in over 2 million driving miles of continuously collected data, calculated the relative frequency (critical incidents divided by opportunities) for each hour of driving and determined odds ratios from this data. Analyses found an elevated risk in the first driving-hour, but no consistent significant difference between hours 2 through 11. Analyses on time-of-day, where incident rates were calculated for each of the 24 hours in the day, were also conducted. The results found a strong positive correlation with national traffic density data.

An important factor to keep in mind when considering the results of the Hanowski studies is that driver performance was assessed through the occurrence of critical incidents (crashes, near-crashes, and crash-relevant conflicts), whereas many of the previous studies were based on crash data or data involving drivers who were in crashes. There were only a few crashes in this study and relatively few critical incidents in the $10^{th}$ and $11^{th}$ hours. In addition, since near-crash events do not impose measurable costs on society, it is unclear that the lack of a finding of no significant increase in critical events is relevant to evaluating the costs and benefits of the proposed changes. The Agency concedes that, in general, an increase in critical incidents is a reasonable measure of some increase in crash risk, so the lack of a statistically significant finding of increased risk may be evidence that TOT is not a problem. It should be noted, however, that the study (and most other studies) did not account for breaks taken during the work day, for total duty time on the day of the crash or incident, or duty time during that week, all of which may affect fatigue at any particular hour. The Hanowski study used a computer program to identify the start of the work day, which means that it is also not possible to know whether the first hour is the first hour after a 10-hour or more break, after a shorter (illegal) period, or even at the end of long day. This study must be viewed in light of other studies discussed above, whose findings are consistent with studies of accident rates associated with long hours in other industrial settings [Folkard, S. & Lombardi, D., (2006)]. Despite this study, therefore, the weight of the evidence, when considering all the research conducted on this issue, indicates that some level of TOT risk should be accounted for in our evaluation.

## 4.3 Evaluating Crash Risk for Each Hour of Driving

Given the widely varying rates in the estimate of risk by hour of driving, the Agency used the data available to estimate a function that relates the risk of a fatigue-involved crash to each hour of driving. This analysis most closely parallels Campbell's analysis of the TIFA data. We present our methodology here and then describe how we used it to evaluate a portion of the safety benefits associated with this rule below. We conclude by comparing our estimated TOT functions to those from several of the studies reviewed above, before using the function to estimate safety benefits. The Agency seeks comment on whether its approach to estimating its TOT function is reasonable given the lack of good exposure data. The Agency is interested in any suggestions for improving its approach for estimating TOT effects, especially information on where it might obtain better data on exposure and other driver characteristics that would enable it to improve its estimation of how or whether crash risk varies over successive hours of daily driving.

### *4.3.1 Data Analysis and Methodology for Estimating Our TOT Function*

The goal of the analysis is to find the change in fatigue-related crash risks that would result from eliminating driving in the 11th hour for Option 2. Assuming motor carriers will still deliver the same volume of freight, even without the 11th hour, we can presume that driving not done in the 11th hour will be done by additional drivers, in somewhat shorter trips. There will still be crashes in those shorter trips; indeed, there will still be fatigue-related crashes in these shorter trips. What must be calculated, then, is the average fatigue-related crash rate in trips that allow the 11th hour compared to the rate in the replacement trips that do not.

The analytical approach to adding an explicit TOT effect to the fatigue model is to determine a functional relationship between TOT and the measured percentage of crashes attributable to fatigue, relative to typical fatigue levels, and to use that relative risk to scale up the overall fatigue crash risk for driving hours with above-average fatigue percentages. All estimated fatigue crash risks are then scaled in such a way as to yield an average fatigue crash risk of 13 percent under baseline conditions, which is the rate projected for long-haul driving in the LTCCS.

In the past, FMCSA has used TIFA data from 1991 through 2002 to derive a functional relationship between TOT and the percentage of crashes caused by fatigue. For each TOT level from the 1st hour through the 12th, FMCSA computed the average percentage of crashes caused by fatigue. As TOT increased, the data showed a strong increase in the ratio of fatigue-coded crashes to all crashes. The approach to estimating the effects of long driving hours on crash risks assumes that higher ratios of fatigue-related crashes to total crashes imply higher crash rates. It is mathematically possible, though, that the increase in this ratio comes about because the denominator falls as driving hours increase, not because fatigue increases. In other words, falling rates of crashes due to weather, mechanical failure, traffic, or road conditions, as each driver accumulates more hours on the road, could make it appear that fatigue is a growing problem, whereas it is actually stable. The Agency has no evidence, however, for a pattern in which greater hours on the road would be associated with systematic reductions in crash causes other than fatigue. Another problem with the approach of using the increase in fatigue-coded crashes as a measure of the TOT effect is that the determination of fatigue involvement is somewhat subjective. Accident inspectors may be more likely to code crashes as fatigue-related if the driver has been on the road longer or if it is late at night, thus fatigue coding could be influenced by knowledge of drivers' schedules or the time of day on the part of the person coding the factors related to a crash. Again, the Agency has little evidence that this coding bias is a significant problem. Extremely few data points were available for TOT levels beyond 12. The original analysis modeled the TOT relationship as a cubic function, which appeared to fit the data well. To make it possible to use this function with limited data without introducing unreasonable variability for the estimated fatigue percentage at high TOT levels, the TOT and fatigue percentages for the crashes beyond 12 hours are averaged over all the crashes. The average percentage of fatigue-coded crashes for these 101 crashes was 24.75 percent, and the average TOT was 16.73 hours.

### *4.3.2 Use of an Estimated Function*

The decision to fit a function to the data, rather than use the average probabilities of fatigue-coded crashes seen in the data, is a reasonable choice given the very small amount of data at high TOT levels. A review of the TIFA data from 1991-2002, shown in Exhibit 4-4, helps to illustrate this point. The 1991-2002 data give, for each hour of driving, the total number of crashes and the total number of crashes that were deemed fatigue-related. For example, in the eleventh hour of driving, there were a total of 94 crashes, of which 9 crashes (9.6 percent) were fatigue-coded. The relationship between the number of hours of driving and the probability that a crash in that hour is fatigue-coded provides the basis for the estimation.

For many of the TOTs, the observed proportion of crashes that were fatigue-coded is not a good estimate of the long-run probability of future crashes being fatigue-coded. If the probability of a fatigue-coded crash is low and the total number of observed crashes is relatively small (say, a few hundred or less), then the observed proportion will be a poor estimate of the true proportion because the observed proportion will have a large variance. This is shown by the last four columns in Exhibit 4-4, which give 95 percent and 99 percent confidence intervals for the true proportions based only on the observed proportions at the same hour.

These confidence intervals are based on the fact that the distribution of the number of fatigue-coded crashes at hour h of driving is a binomial distribution, where the number of trials, n, is the total number of crashes at hour h, and the "success" probability is the long run probability that a crash at hour h was fatigue-coded. This assumes that the n crashes occurred independently. For example, at h = 11, the observed percentage was 9/94 = 9.6 percent and the 95 percent confidence interval is the wide range from 4.5 percent to 17.4 percent. For hours 10 or less, the total number of crashes is much higher and the confidence intervals are much narrower, but for 15 or more hours of driving, when the number of observations drops off drastically, the intervals are very wide.

**Exhibit 4-4. 1991-2002 TIFA Crash Data Showing Confidence Intervals**

| TOT (Hour of Driving) | Total Fatigue-coded Crashes | Total Crashes | Percentage of Crashes That Were Fatigue Related | 95% Confidence Interval for Percentage* | | 99% Confidence Interval for Percentage[a] | |
|---|---|---|---|---|---|---|---|
| | | | | Lower | Upper | Lower | Upper |
| 1 | 102 | 10412 | 0.98% | 0.80% | 1.19% | 0.75% | 1.26% |
| 2 | 94 | 5947 | 1.58% | 1.28% | 1.93% | 1.19% | 2.05% |
| 3 | 65 | 4325 | 1.50% | 1.16% | 1.91% | 1.07% | 2.05% |
| 4 | 68 | 4216 | 1.61% | 1.25% | 2.04% | 1.16% | 2.18% |
| 5 | 62 | 3028 | 2.05% | 1.57% | 2.62% | 1.44% | 2.81% |
| 6 | 44 | 2798 | 1.57% | 1.14% | 2.11% | 1.03% | 2.28% |
| 7 | 39 | 1501 | 2.60% | 1.85% | 3.53% | 1.66% | 3.85% |
| 8 | 48 | 1668 | 2.88% | 2.13% | 3.80% | 1.93% | 4.10% |
| 9 | 21 | 641 | 3.28% | 2.04% | 4.96% | 1.74% | 5.54% |
| 10 | 22 | 495 | 4.44% | 2.81% | 6.65% | 2.40% | 7.40% |
| 11 | 9 | 94 | 9.57% | 4.47% | 17.40% | 3.42% | 20.05% |
| 12 | 10 | 115 | 8.70% | 4.25% | 15.41% | 3.31% | 17.70% |
| 13 | 8 | 32 | 25.00% | 11.46% | 43.40% | 8.66% | 48.92% |
| 14 | 0 | 17 | 0.00% | 0.00% | 19.51% | 0.00% | 26.78% |
| 15 | 1 | 10 | 10.00% | 0.25% | 44.50% | 0.05% | 54.43% |
| 16 | 3 | 10 | 30.00% | 6.67% | 65.25% | 3.70% | 73.51% |
| 17 | 2 | 6 | 33.33% | 4.33% | 77.72% | 1.87% | 85.64% |
| 18 | 1 | 6 | 16.67% | 0.42% | 64.12% | 0.08% | 74.60% |
| 19 | 0 | 2 | 0.00% | 0.00% | 84.19% | 0.00% | 92.93% |
| 20 | 0 | 3 | 0.00% | 0.00% | 70.76% | 0.00% | 82.90% |
| 21 | 1 | 2 | 50.00% | 1.26% | 98.74% | 0.25% | 99.75% |
| 22 | 1 | 2 | 50.00% | 1.26% | 98.74% | 0.25% | 99.75% |
| 23 | 0 | 1 | 0.00% | 0.00% | 97.50% | 0.00% | 99.50% |
| 24 | 1 | 2 | 50.00% | 1.26% | 98.74% | 0.25% | 99.75% |
| 28 | 2 | 2 | 100.00% | 15.81% | 100.00% | 7.07% | 100.00% |
| 31 | 0 | 1 | 0.00% | 0.00% | 97.50% | 0.00% | 99.50% |
| 34 | 3 | 3 | 100.00% | 29.24% | 100.00% | 17.10% | 100.00% |
| 36 | 2 | 2 | 100.00% | 15.81% | 100.00% | 7.07% | 100.00% |

[a] Calculation of confidence intervals use a binomial model of fatigue probabilities for each TOT

Thus, relying on the percentage of fatigue crashes for individual TOT hours would subject the analysis to great uncertainty, because random factors can cause large changes in measured percentages of small numbers. The data for the 13$^{th}$ hour, for instance, shows 25 percent fatigue crashes, while the 14$^{th}$ hour shows 0 percent fatigue; the 11$^{th}$ hour shows 9.6 percent, while the 12$^{th}$ shows only 8.7 percent. Clearly, none of these disparate values are themselves precise measures of what would be seen if enough data were available. Much better predictions of the probabilities of crashes being fatigue-related can be obtained by the standard statistical approach of fitting parametric statistical models to all the data, so that the probability is a smooth function of the TOT. In this manner the probabilities can be estimated more precisely, and can be estimated for all values of h, not just the values in the data. For example, we can use interpolation to estimate the probability for 25, 26, and 27 hours of driving, which were not included in the data set but were within the range of driving hours in that set. The need to fit a function to the data, using the data from the large volumes of crash experience at low TOT levels, was in fact recognized by the appeals court in the 2004 decision.[13]

### *4.3.3 Estimation of the TOT Function*

We have estimated the function using the following approach, which seems appropriate given the nature of the data: A logistic model was used to predict fatigue involvement probabilities for each hour of driving, also described as the TOT. This approach replaced the use of the cubic function and obviated the need to combine data points at high TOT levels. Logistic regression is a standard statistical approach that ensures that the predicted probabilities will be between zero and one. The logistic regression takes the form

$$\mathit{Logit}\{\mathit{Prob}\ (\text{Crash is fatigue-coded} \mid \text{crash occurred at hour } h \text{ of driving})\} =$$
$$a0 + a1 \times h + a2 \times h^2 + a3 \times h^3 + \ldots + ak \times h^k,$$

where k >= 0 is some integer and the coefficients a0, a1, …, ak are unknown parameters. The logit function is defined as

$$\mathit{logit}(p) = \log\{p/(1-p)\},$$

where log denotes the natural logarithm.

We fitted this model to the 1991-2002 data using the method of maximum likelihood. The value of k was found by a sequential procedure under which terms $ak \times h^k$ were added to the model until the score chi-square statistic for the added term was not statistically significant at the 5 percent level. The selected model was a quadratic model with k = 2:

$$\mathit{Logit}\{\mathit{Prob}\ (\text{Crash is fatigue-coded} \mid \text{crash occurred at hour } h \text{ of driving})\} =$$
$$a0 + a1 \times h + a2 \times h^2.$$

The estimated parameter values and their standard errors are shown in Exhibit 4-5. The standard error is the estimated standard deviation of the estimated coefficient.

Exhibit 4-5. Fitted Logistic Model to 1991-2002 Data

| Parameter | Estimated Value | Standard Error |
|---|---|---|
| a0 | -4.6342 | 0.0911 |
| a1 | 0.1226 | 0.0265 |
| a2 | 0.0034 | 0.0016 |

[13] United States Court of Appeals for the District of Columbia Circuit, argued April 13, 2004, decided July 16, 2004, No. 03-1165, Public Citizen, *et al*., Petitioners *v*. Federal Motor Carrier Safety Administration, Respondent, p. 16.

Using the logistic model, the probabilities that a crash is fatigue-coded can be estimated for any value of h. The predicted probabilities for h <= 20 and their 95 percent confidence intervals are given in Exhibit 4-6. One obvious feature of this model is that the predicted probabilities of crashes being fatigue-coded increase as the TOT increases, which is the expected pattern assuming that increased TOT leads to increased fatigue and therefore a greater chance of a crash attributable to that fatigue; the observed probabilities often do not follow this pattern.

Exhibit 4-6. Confidence Intervals for Percentages of Crashes That Were Fatigue-coded Using the Logistic Model Applied to 1991-2002 TIFA Data

| TOT (Hour of Driving) | Observed Percentage of Crashes That Were Fatigue-Coded | Predicted Percentage of Crashes That Were Fatigue-Coded | 95% Confidence Interval for Predicted Percentage | |
|---|---|---|---|---|
| | | | Lower | Upper |
| 1 | 0.98% | 1.09% | 0.95% | 1.25% |
| 2 | 1.58% | 1.24% | 1.12% | 1.38% |
| 3 | 1.50% | 1.43% | 1.30% | 1.56% |
| 4 | 1.61% | 1.65% | 1.51% | 1.79% |
| 5 | 2.05% | 1.91% | 1.75% | 2.09% |
| 6 | 1.57% | 2.24% | 2.03% | 2.47% |
| 7 | 2.60% | 2.63% | 2.36% | 2.93% |
| 8 | 2.88% | 3.11% | 2.75% | 3.51% |
| 9 | 3.28% | 3.70% | 3.23% | 4.23% |
| 10 | 4.44% | 4.42% | 3.81% | 5.12% |
| 11 | 9.57% | 5.31% | 4.51% | 6.25% |
| 12 | 8.70% | 6.41% | 5.35% | 7.67% |
| 13 | 25.00% | 7.77% | 6.33% | 9.50% |
| 14 | 0.00% | 9.44% | 7.49% | 11.83% |
| 15 | 10.00% | 11.49% | 8.85% | 14.80% |
| 16 | 30.00% | 14.00% | 10.41% | 18.58% |
| 17 | 33.33% | 17.05% | 12.22% | 23.29% |
| 18 | 16.67% | 20.72% | 14.29% | 29.06% |
| 19 | 0.00% | 25.06% | 16.64% | 35.92% |
| 20 | 0.00% | 30.11% | 19.28% | 43.73% |

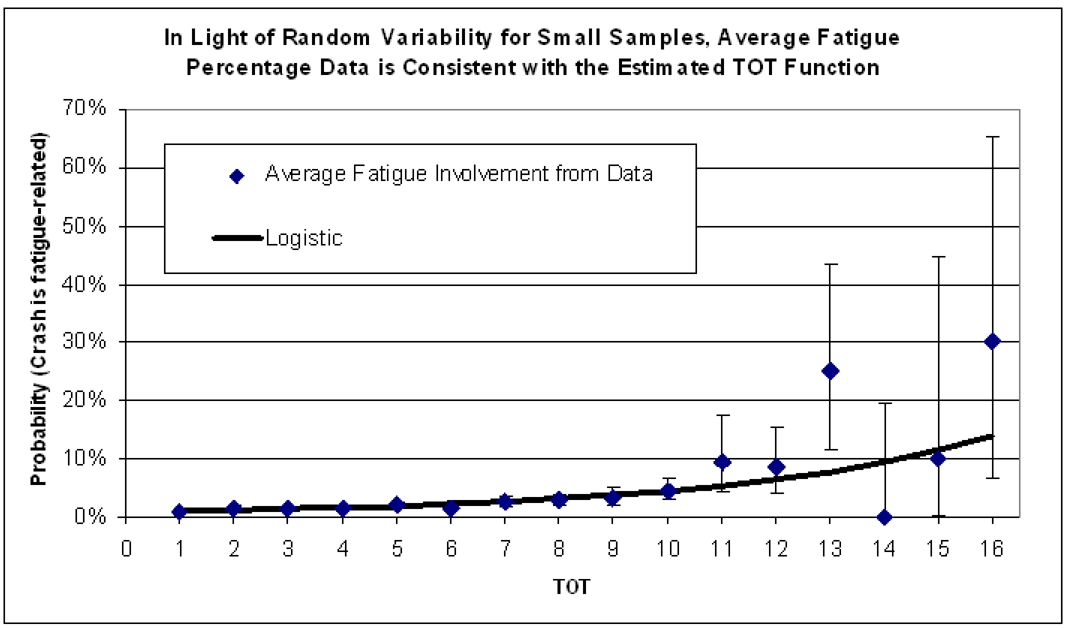
Note that the observed percentages of fatigue-coded crashes often are not included in the 95 percent confidence intervals for the predicted percentages. For example, for h = 11, the observed percentage is 9.6 percent but the 95 percent confidence interval for the predicted percentage ranges from 4.51 percent to 6.25 percent. The predicted results are nonetheless consistent with the observed data because of the large uncertainty in the observed percentages, as shown in Exhibit 4-4. The following Exhibit 4-7 demonstrates this point by comparing the confidence intervals for the observed percentages with the confidence intervals for the predicted percentages over the range h = 9, 10, 11, 12, 13, and 14. Except for h = 13, the confidence intervals for the observed percentage contain the confidence intervals for the predicted percentage.

Exhibit 4-7. Comparison of 95% Confidence Intervals for Observed and Predicted Percentages Using 1991-2002 Data

| TOT (Hour of Driving) | Observed Percentage of Crashes That Were Fatigue-Coded | 95% Confidence Interval for Observed Percentage | | Predicted Percentage of Crashes That Were Fatigue-coded | 95% Confidence Interval for Predicted Percentage | |
|---|---|---|---|---|---|---|
| | | Lower | Upper | | Lower | Upper |
| 9 | 3.28% | 2.04% | 4.96% | 3.70% | 3.23% | 4.23% |
| 10 | 4.44% | 2.81% | 6.65% | 4.42% | 3.81% | 5.12% |
| 11 | 9.57% | 4.47% | 17.40% | 5.31% | 4.51% | 6.25% |
| 12 | 8.70% | 4.25% | 15.41% | 6.41% | 5.35% | 7.67% |
| 13 | 25.00% | 11.46% | 43.40% | 7.77% | 6.33% | 9.50% |
| 14 | 0.00% | 0.00% | 19.51% | 9.44% | 7.49% | 11.83% |

Exhibit 4-8 below displays these concepts graphically; the bars show the 95 percent confidence intervals for the fatigue-coded percentages in individual hours.[14]

**Exhibit 4-8. Comparison of Logistic TOT Function to Confidence Bounds Around Fatigue Percentages**




[14] The relationship between TOT and fatigue seen in these data might be related, in part, to difference in sleep, work, and time awake, which are in turn correlated with TOT. Unfortunately, the data set on which this analysis was based did not include information on these other variables, so it was not possible to determine the independent effect of TOT, holding other variables constant. Because some of the apparent effect of TOT is likely to be due to these other variables, we consider the functional relationship used here to be a conservative measure of the size of the independent effect of TOT (in that the function is likely to overstate that effect). Also, to the extent that the 2003 HOS increased opportunities to sleep and reduced opportunities to drive after long hours awake, the current relationship of TOT to fatigue might be weaker than it appears here. As discussed further below, using data collected after 2003 does reduce the TOT effect, but to a small degree only.

### 4.3.4 *"Bootstrap" Analysis of the Difference in Predicted Probability for Hour 11 and Mean Predicted Probability for Hours 1 to 10*

The predicted probabilities in Exhibit 4-7 can be used to calculate the difference between the mean probability for hours of driving 1 to 10 and the probability for hour 11, which is a measure of the change in fatigue-coded crashes that would occur if an hour of driving were shifted from the $11^{th}$ hour to an average of the earlier hours. The mean probability for hours of driving 1 to 10 equals 2.34 percent and the probability for hour 11 equals 5.31 percent, giving a difference of 2.97 percent (5.31% - 2.34%). Since this estimated difference is a complicated function of the parameters a0, a1, and a2, the uncertainty of the estimated difference cannot be calculated analytically. For this calculation we used a bootstrap simulation technique, as described below.

The raw data contain results for a total of 35,341 crashes (not including cases with missing values for TOT or fatigue), of which 10,412 occurred in hour of driving 1, 5,947 occurred in hour of driving 2, and so on. For each of 1,000 bootstrap simulations, we used the fitted logistic model to simulate the 35,341 crashes, deciding for each crash whether or not it was fatigue-coded. Thus for the first simulated crash in the first hour of driving, the logistic model predicts that the probability of being fatigue-coded equals 1.09 percent, so this crash is given a 1.09 percent probability of being fatigue-coded. Similar calculations are made for the remaining 10,411 crashes in the first hour of driving. Thus the simulated number of fatigue-coded crashes in the first hour of driving has a binomial distribution with 10,412 trials and "success" probability 1.09 percent. A similar calculation applies to all the other crashes in this first bootstrap simulation giving a total of 35,341 simulated crashes (either fatigue-coded or not fatigue-coded). The logistic model with k = 2 is fitted to the simulated data and the predicted difference between the mean probability for hours of driving 1 to 10 and the probability for hour 11 is calculated for this fitted model. This procedure is repeated for 1,000 bootstrap simulations, producing 1,000 estimated differences ranging from 1.93 percent to 4.03 percent. Standard statistical theory shows that this distribution of 1,000 differences will be a good approximation to the true uncertainty distribution of the difference. Therefore, as shown in Exhibit 4-9, we can estimate a 95 percent confidence interval for the difference as the range from the $26^{th}$ highest difference to the $975^{th}$ highest difference, which was 2.32 percent to 3.65 percent, since there are 25 + 25 = 50 differences (50/1000 = 5%) outside of this range. Similarly we can estimate a 99 percent confidence interval for the difference as the range from the $6^{th}$ highest difference to the $995^{th}$ highest difference, 2.15 percent to 3.91 percent, since there are 5 + 5 = 10 differences (10/1000 = 1%) outside of this range.

Exhibit 4-9. Bootstrap Confidence Intervals for the Probability of a Crash Being Fatigue Related in Hour 11 Minus the Mean Probability of a Crash Being Fatigue Related for Hours 1 to 10

| Estimate | 95% Lower Bound | 95% Upper Bound | 99% Lower Bound | 99% Upper Bound |
|---|---|---|---|---|
| 2.97% | 2.32% | 3.65% | 2.15% | 3.91% |

As mentioned previously, one difficulty with measuring the risk of driving by hour is the lack of crash and exposure data by driving hour. TIFA data provides a reasonably good estimate of the number of fatal crashes that occur in each hour of driving, but does not measure how much driving occurs in each hour or the total number of non-fatal crashes by hour. Thus, TIFA data alone cannot provide an estimate of the risk of crashes per hour of driving.

One possible solution to this is to use survey data, such as that used in previous HOS rulemaking proceedings, as a means for estimating driving by hour. We seek comment from the public on alternative approaches and on what those alternative approaches might reveal about crash risk.

## 4.4 DETAILED EXPLANATION OF THE ESTIMATION OF SAFETY BENEFITS

This section explains more specifically how the safety functions described above are used to quantify and monetize the changes in crash risks resulting from the options. The step-by-step explanation of how the numbers are developed is based on the first of the three regulatory alternatives (Option 2), but the method applies to the others as well. To calculate the safety benefits of the new HOS rule provisions, we use the same categorization of drivers that we use in the calculation of the costs of operational changes. The calculation of safety benefits also involves the average changes in driving hours per week, as estimated in the previous chapter as part of the estimation of the cost of operational changes.

The safety benefits of the HOS rule changes can be broken down into two effects: the benefits of the restriction on daily driving time and the cumulative effect on the hours worked per week. To estimate the benefit of the reduction in daily driving time, we use the reduction in hours for each category of drivers that was calculated in the previous chapter on operational changes. A slightly different calculation is used for the purpose of estimating the safety benefits. In the previous chapter, when the total hours lost due to the restriction of driving to 10 hours were calculated, a portion of the impact was subtracted to avoid double-counting the impact of the restriction in daily work time. For the estimate of the safety impacts of eliminating the 11$^{th}$ hours of driving, the issue of double-counting does not apply: all of the 11$^{th}$ hours of driving in each driver's week are eliminated (though some of them can be shifted to another day, turning an 8-hour day into a 9-hour day). The number of affected 11$^{th}$ hours per week can thus be found by multiplying the percentage of tours of duty with 11$^{th}$ hours by the number of tours of duty per week. For example, for the high intensity drivers, this calculation results in a total of 1.5 hours affected (25% x 1 hour x 6 tours/week). This calculation is repeated for each category of drivers to obtain the total reduction of hours of driving in the 11$^{th}$ hour due to the 11$^{th}$ hour restriction, per driver (see Appendix D).

Next, the total lost hours due to the 11$^{th}$ hour restriction is multiplied by the percentage that each driver category comprises of the total driver population and by 50 weeks per year to obtain the annual total hours affected (that is, lost or reallocated to another work day) for each driver category. For example, for the high intensity drivers, this resulted in a total of 14.25 hours (1.5 x 19% x 50) affected per year per driver. For each category of drivers, we repeat this calculation and sum them to obtain a total of 56.25 hours affected per year per driver due to the 11$^{th}$ hour restriction. We then multiply this total by the total number of drivers to obtain a total of 90 million (56.25 hours x 1,600,000 drivers) hours lost per year due to the 11$^{th}$ hour restriction.

In calculating the hours affected due to the 11$^{th}$ hour restriction, we also account for the fact that some of that time could be shifted to another day of driving. For each of the categories of drivers, the total hours affected per year per driver are multiplied by the percent of an hour which that group of drivers would be able to shift to another day. The total hours lost for the moderate, high, very, and extreme intensity groups are multiplied by 0.45, 0.35, 0.25, and 0.15, respectively, based on our judgments about the fraction of driving done in the 11$^{th}$ hour that could be made up by shifting it to another day. The totals for the different driver groups are summed to obtain the total number of hours shifted to another day. We then divide the sum of the hours shifted to another day by the sum of the total hours lost to determine the percentage of hours shifted relative to the hours lost. This results in an estimated total of 68 percent of the baseline driving in the 11$^{th}$ hour that is lost due to the 11$^{th}$ hour restriction, rather than being shifted to another driving day.

The total of hours lost due to the 11$^{th}$ hour restriction is then multiplied by the per-hour safety benefit due to eliminating driving in the 11$^{th}$ hour. There are several steps involved in calculating the per-hour benefit of eliminating driving in the 11$^{th}$ hour. The first step is to calculate the excess risk of crashes for driving in the 11$^{th}$ hour, relative to driving in the hours that would replace the driving that can no longer be done in the 11$^{th}$ hour. This step recognizes, explicitly, that virtually the same amount of freight would need to be delivered, whether or not 11 hours of driving are allowed; and, therefore, there would be increases in driving in other hours in response to a prohibition on the use of the 11$^{th}$ hour. To the extent that existing drivers are not able to shift some driving to another work day, we assume that the lost driving hours are reallocated to an added driver either in the same or a different carrier. That added driver is assumed to drive a typical mix of hours up to, but not beyond, 10 hours per day (the assumed limit) – that is, driving 5 hours as often as existing drivers do so, driving 9 hours as often as existing driver do so, and so forth. Because the hours shifted to added drivers would be a typical mix of hours 1 through 10, we assume that the risk of a fatigue-related crash would be no different from the risk of a fatigue-related crash when no more than 10 hours are permitted. The per-driving-hour reduction in the risk of fatigue is then the risk of fatigue in the 11$^{th}$ hour by itself minus the typical level of fatigue.

Our estimate of the risk of fatigue in the 11$^{th}$ hour is based on an assumed average level of fatigue involvement in crashes, combined with a TOT function (discussed below) that expresses how fatigue involvement changes with hours of driving. The average level of fatigue involvement is uncertain, largely due to the difficulty of accurately measuring fatigue. For this analysis, our baseline level of fatigue involvement in crashes is based on the LTCCS data. This data was collected during the 2001-2003 calendar years.

In comparing fatigue involvement with other data sources, it is important to examine the proportion of single vehicle crashes in the data, because fatigue is overrepresented in single vehicle crashes. The LTCCS is an example of this phenomenon. Truck driver fatigue was coded as a factor in 13 percent of all crashes in the LTCCS, but was a factor in 28 percent of single vehicle truck crashes. To confirm that single vehicle crashes are not overrepresented in LTCCS, we compare the percentage of single vehicle crashes in LTCCS data with the percentage of single vehicle crashes recorded in FARS data for the same years. Single vehicle truck crashes make up 21 percent of the LTCCS crashes, and 17.5 percent of the FARS crashes from the same years. Given the small difference in these percentages, it appears that single vehicle crashes may be slightly overrepresented in LTCCS, but within what would be considered the margin of error.

Another factor that militates against fatigue being overrepresented in LTCCS is that LTCCS crash investigators took a very conservative approach to coding crash factors. LTCCS investigators coded crash factors as unknown when no cause of the crash could be determined. As a result, 13.24 percent of crashes recorded in LTCCS were coded as having an unknown cause. Presumably, a portion of these crashes were caused by fatigue, even though fatigue could not be identified definitively as a contributing factor by the crash investigator. Given the conservative approach to coding crash causes and the relatively small difference in single vehicle crashes included in LTCCS compared to FARS data from the same years, we are reasonably confident that the fatigue involvement rate in LTCCS is accurate. Because these figures are estimates, we have considered a range of fatigue involvement in conducting the safety benefit analysis for this rule. A lower value of 7 percent is employed in sensitivity analyses, based on the 8.15 percent value found though a careful reanalysis of TIFA data conducted for the RIA for the 2003 HOS rule and projected fatigue reductions under the 2003 HOS rule. A higher value of 18 percent is also used for sensitivity analysis, chosen to be roughly as far above the LTCCS value of 13 percent as the 8.15 percent pre-2003 estimate is below 13 percent. We are confident that the range of baseline fatigue involvement, from 7 to 18 percent, is reasonable given the evidence we have from FARS, LTCCS, and other data sources.

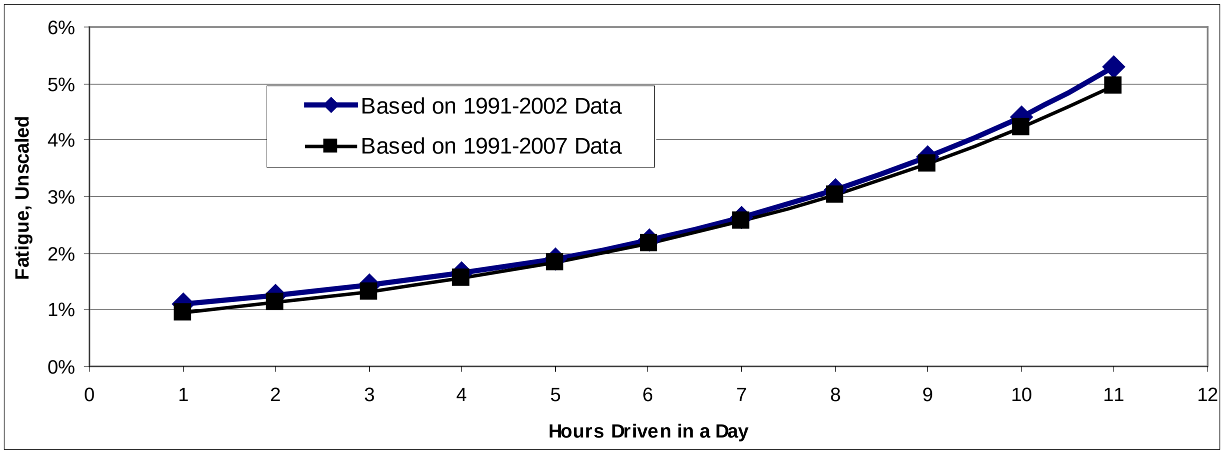
As discussed above, a logistic TOT function was estimated for the RIA for the 2007 HOS rule, using data from TIFA for the years 1991 through 2002 (when only 10 hours of driving were allowed for interstate operations). This function (shown below in Exhibit 4-10 and described above in section 4.3) was presented in the RIA for the 2007 HOS rule, and showed the 11$^{th}$ hour with a 5.31 percent chance of fatigue, compared to an industry-wide average below 2 percent. Thus, the chance of fatigue in the 11$^{th}$ hour is more than twice as great as in the average hour.

Exhibit 4-10. Fitted Logistic Model to 1991–2007 Data

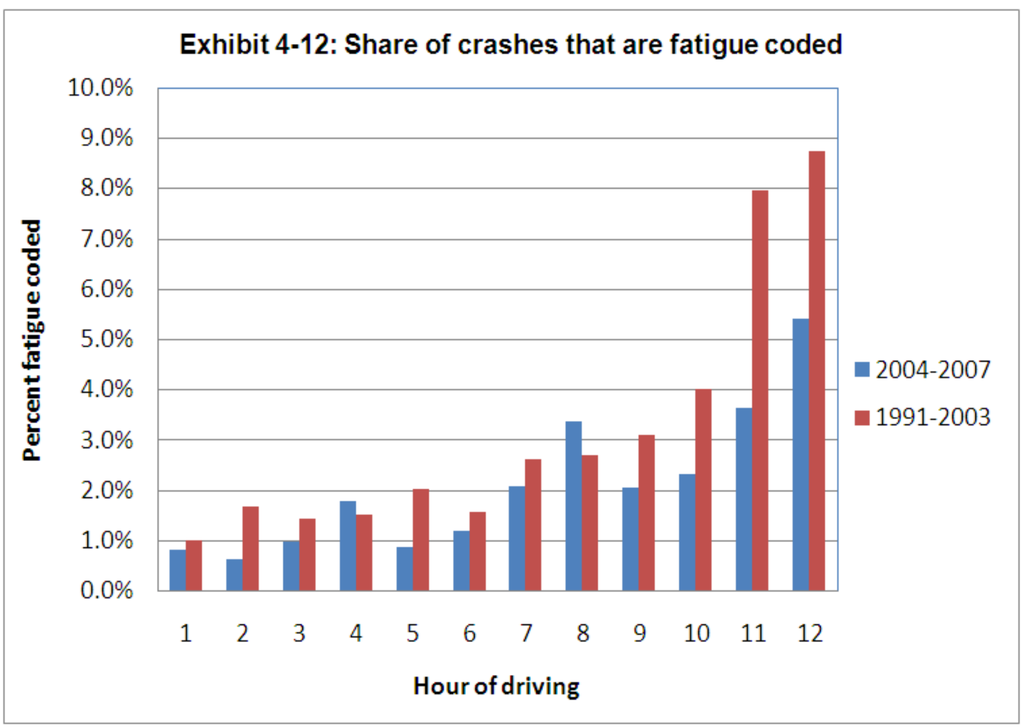
| Parameter | Estimated Value | Standard Error |
|---|---|---|
| a0 | -4.80834 | 0.077051 |
| a1 | 0.164463 | 0.020058 |
| a2 | 0.000405 | 0.00105 |

For this analysis, we have re-estimated the TOT function using additional TIFA data for the years 2003 through 2007, in combination with the data from 1991 through 2007. Exhibit 4-10 presents the parameters for this updated model. Exhibit 4-11 shows the original and the updated TOT functions on the same graph; they differ only slightly.

**Exhibit 4-11. Percent of Fatigue Involvement in Crashes by Hour of Driving (Showing 2007 Function and the Newer Function)**




It should be noted, however, that using a fitted curve derived from both pre- and post-2003 data somewhat masks the differences in data from these two periods. Exhibit 4-12 demonstrates this difference. There is a relatively large difference between these periods in the 11$^{th}$ hour, for which driving was mostly illegal before 2003, although the general trend of increasing fatigue-coding is present in both series. Also, differences of the same or larger relative magnitude are observed in earlier hours (e.g. the 2$^{nd}$ and 5$^{th)}$ that were legal under both rules. In other hours fatigue-coding was greater in the 2004-2007 than in the pre-2003 series. This exhibit indicates that 11$^{th}$-hour risk of fatigue-coded crashes was considerably lower post 2004, although this may be random variation because relatively few crashes are fatigue coded in any given year.

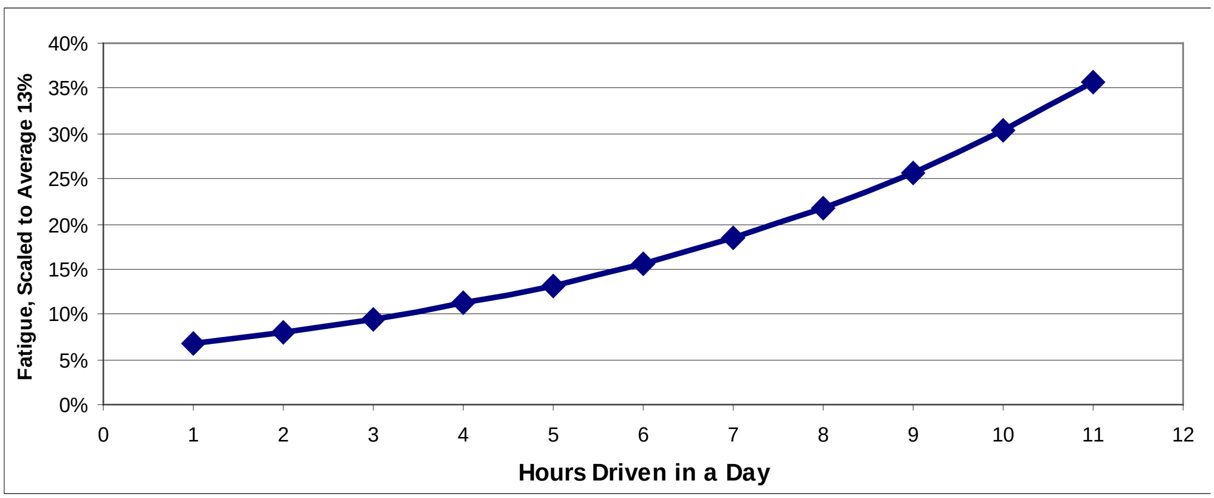


The risk in the average hour was calculated using the updated logistic TOT and a distribution of driving hours based on the 2005 FMCSA Field Survey. This analysis showed a fatigue involvement rate of 1.81 percent for average driving patterns. Knowing that TIFA is likely to understate fatigue involvement, we scale the fatigue percentage upward for each hour so that the average fatigue involvement equals 13 percent (in the central case) and either 7 or 18 percent (in the sensitivity cases).

Our function provides a risk estimate for later hours of driving that is larger than that found in the Hanowski,R.J., *et al*. (2009) study (described above), which showed no difference in risk by hour of driving, except that the first hour was found to have a higher crash involvement rate than other hours. In the Hanowski study, the other hours were indistinguishable from one another with regard to crash risk. The Jones and Stein, and Park and Jovanis studies found significantly higher risk associated with later hours of driving than the function we estimated from the TIFA data. We applied this methodology to the LTCCS data as well, following the Campbell analyses described above, and produced results comparable to those obtained from the TIFA data. Considering the various functions available from the research, our TOT effect appears to be reasonable in size.

After scaling up the TOT function to yield a higher average, it predicts just under a 36 percent likelihood of fatigue involvement in the 11th hour when the average fatigue risk is 13 percent. The scaled function is shown in Exhibit 4-13. Shifting an hour from the 11th to a typical driving hour is, therefore, assumed to reduce the fatigue crash risk for the affected hour by 23 percent (36% – 13%). Similar calculations are made for the lower and upper fatigue sensitivity cases.

**Exhibit 4-13. Percent of Fatigue Involvement in Crashes by Hour of Driving (Scaled Function)**



A slightly different calculation is made to estimate the reduction in risk for hours that a given driver can shift to another day. These driving hours would be, in essence, added to the end of a driving day that would otherwise have been of typical length for that driver.[15] Driving days can be of various lengths, but for the hard-driving individuals, who are most affected by a driving hour limit, they are likely to be relatively long. We assume, for simplicity, an equal mix of driving days from 5 to 9 hours long, so that the shifted hour would fall between the 6th hour and the 10th hour. The average TOT risk for adding driving in these hours would be above that for the typical hour; by applying the logistic TOT function to these hours (after scaling it up to average 13% fatigue), we estimate their risk to be 22.3 percent. Thus, shifting an hour of driving from the 11th hour (with a projected fatigue risk of about 35.7 percent) to another day (with a projected risk of about 22.3 percent) would reduce the crash risk by 35.7 percent minus 22.3 percent, or 13.4 percent.

The next step is to calculate the value of these reductions in fatigue crash risk per hour by multiplying by the average level of costs of heavy-duty truck crashes per hour of driving. To calculate this number, we start with the estimated cost of all long-haul crashes of $37.3 billion (2008$) (based on an estimate of almost 434,000 large truck crashes), the estimated average damages of $148,000 per crash, and an estimate of the fraction of large truck crash damages associated with the long-haul industry [FMCSA (2002a)].[16] We then divide this number by the estimated number of long-haul drivers (1,600,000) and also by the average hours driven per year per driver (2,257).[17] This calculation results in an average crash cost per hour of driving of $10.33.

Once we calculate the average crash cost per hour of driving, we next calculate the value per hour of the change in risk from removing the 11th hour. This value per hour is calculated for two different scenarios: the restricted 11th hour of driving being reallocated to a new driver, and the restricted 11th hour of driving being shifted to another driving day by the same driver. For calculating the value per hour of the change in risk when the restricted 11th hour of driving is reallocated to a new driver, we first determine the change in the percentage of fatigue involvement when the restricted 11th hour of driving is reallocated to a new driver. The change in the fatigue level is thus the scaled percent of fatigue involvement in the 11th hour (35.7 percent) minus the average percent fatigue involvement for all other hours (13 percent), or 22.7 percent (35.7% – 13%). We next multiply this change in the percent fatigue involvement by the average crash cost per hour of driving. This results in a value of $2.35 (22.7% x $10.33) per hour of the change in fatigue risk from removing the 11th hour when the restricted driving is reallocated to another driver.

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[15] One could also think of this hour of driving being added to the beginning of the next day, but then the driving that would have been done in the first hour of that next day would be pushed into the second hour, and the second hour into the third, and so forth for the rest of the day. From either perspective, the net effect will be an increase in driving at the end of a typical day of driving.

[16] The long-haul segment accounts for approximately 58 percent of large truck crash damages, as calculated in the 2003 RIA [FMCSA (2002a)]. The total number of crashes and cost per crash is taken from FMCSA, Excel file "CrashCostTableTool.xls."

[17] Average hours worked per year is calculated using data from the 2005 FMCSA Field Survey. The average hours worked per year is the product of the average hours of driving per day per driver (7.7) and the average days worked per year (295).

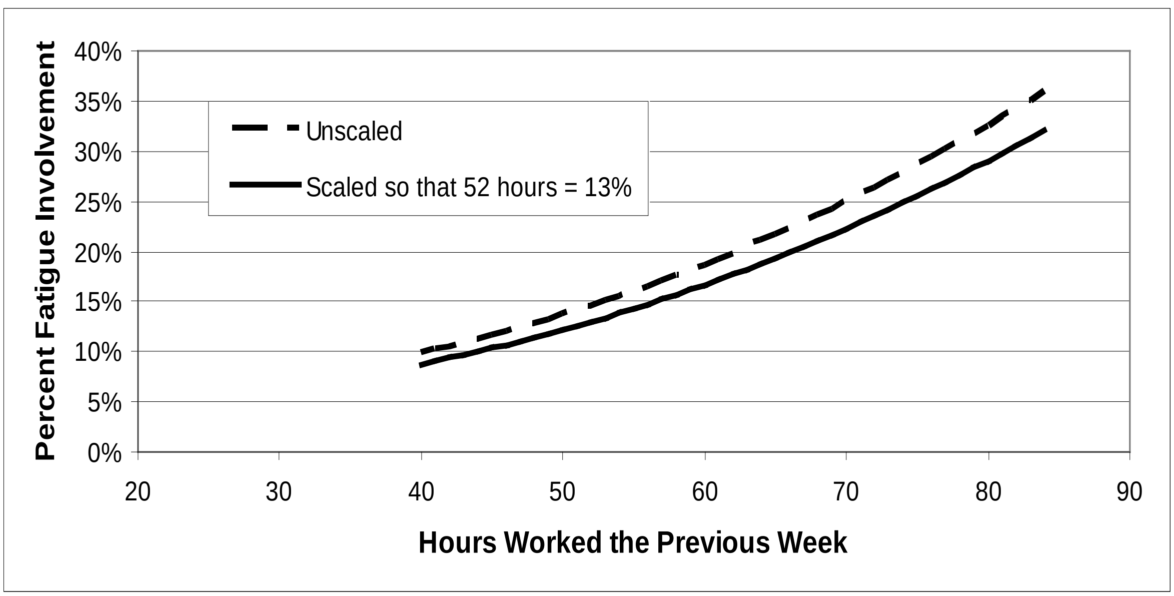
We repeat this calculation for the second scenario where the restricted 11th hour driving is shifted to other days by the same driver. We make a similar calculation for the change in fatigue level, except for this calculation we use the average percent fatigue involvement for hours 6 through 10 of driving time, assuming that the driver would shift the time to the end of one of his or her other driving days. For this scenario, the change in fatigue level is thus the scaled percent fatigue involvement in the 11th hour (35.7 percent) minus the average percent fatigue involvement for hours 6 through 10 (22.3 percent), or 13.4 percent (35.7% – 22.3%). We next multiply this change in the percent fatigue involvement by the average crash cost per hour of driving. This results in a value of $1.38 (13.4% x $10.33) per hour of the change in fatigue risk from removing the 11th hour when the restricted driving is redistributed to other days by the same driver.

Now that we have an estimated value per hour of the change in risk from removing the 11th hour for both of the possible scenarios discussed above, we calculate the weighted value per hour of the change in risk. For this calculation, we use the percentage of the restricted 11th hour of driving that would be lost and redistributed to another driver, rather than shifted to another day by the same driver, which is calculated above (68 percent). We obtain the weighted value per hour of the change in crash risk by taking the sum of the value per hour for hours that are lost and redistributed to another driver ($2.35) multiplied by the assumed percent of hours for this scenario (68 percent) and the value per hour for hours that are shifted to another driver ($1.38) multiplied by the assumed percent of hours for this scenario (100% - 68% = 32%). This calculation results in a weighted value per hour of the change in fatigue risk of $2.04 ([$2.35 x 68%] + [$1.38 x 32%]). This weighted value per hour of the change in fatigue risk is then multiplied by the hours per year lost due to the 11th hour restriction, calculated above (90 million), to obtain a total of $184 million for the safety benefit due to the change in daily driving time. (This value is shown for Option 2 in Exhibit 6-5, for the 13 percent fatigue scenario, rounded to $180 million.) Similar calculations are made using the lower and upper bound fatigue estimates. These other estimates scale in proportion to the estimate shown above with the median fatigue value.

Next, we estimate the safety benefits due to the change in weekly work time. The first step of estimating the safety benefits of reducing weekly work time is to determine the weekly work time for each category of drivers if the proposed new HOS rule were to go into effect. For each category of drivers, we start with the assumed average work time, as shown in Exhibit 2-6, and subtract from it the change in weekly work time as calculated in Chapter 3, section 3.2. For example, for the high intensity group, the estimated change in its weekly work time (1.04 hours) is subtracted from its average weekly work time (60 hours) to obtain a new average weekly work time of just under 59 hours. This change in weekly work time involves a shift in hours per week from an existing driver to another driver driving a typical schedule. As these hours are shifted, the fatigue rate drops from the rate for the driver whose hours have been cut to the rate for a driver at a typical fatigue level.

Next, for each total weekly work time, the number of average hours worked is converted to a fatigue percentage using a cumulative fatigue function estimated using data from the LTCCS. This function is based on the dashed curve in Exhibit 4-14 below, which is a logistic function relating hours worked in the previous week to the likelihood that the truck driver in a crash was judged to be fatigued [FMCSA (2008c), p.12]. This cumulative function is scaled so that the risk for a typical driver, estimated to work about 52 hours per week, has a typical fatigue level (in the central case, of 13 percent). For example, a weekly work schedule of 60 hours per week is associated with a 16.7 percent fatigue level. This is compared to the fatigue level of 13 percent for a driver with an average schedule of 52 hours per week (as described in the industry profile section; the scaled function is also shown in Exhibit 4-14, as the solid curve). We take the difference of the old average weekly work time for each category of drivers and the weekly work time for a typical driver to obtain a difference of 3.7 percent (16.7% – 13%). We next use the average crash cost per hour of driving to determine the value of the change in crash risk for the reduction in crash risk that results from redistributing hours to drivers working less intense schedules. For example, for the high intensity drivers, the $10.33 average crash cost per hour of driving is multiplied by the reduction in weekly work time for this group (1.04 hours) and by the percent reduction in fatigue that results from a driver working an intense schedule versus a driver working an average schedule (3.7 percent). This calculation results in a value of $0.39 for the reduction in weekly working time due to redistributing hours from a driver working an intense schedule to one working an average schedule. This calculation is then repeated for each category of drivers.

**Exhibit 4-14. Percent Fatigue Involvement by Weekly Work Time (Scaled and Unscaled)**




We next estimate the value of drivers reducing their own risk in the following week by driving less intense schedules. For this calculation, we use the average weekly work time if the proposed HOS rule were to go into effect, which was calculated above. For example, for drivers with a high intensity schedule, this results in a new weekly average work time of 59 hours (60 hours – 1.04 hours). We then use the data on the percent fatigue for each hour of driving to determine the fatigue level associated with the change in hours from the original weekly average work time to the average weekly work time if the proposed HOS rule were to go into effect. For example, for drivers with a high intensity schedule, this results in a change in fatigue of 1 percent (16.7% – 15.7%). Recognizing that all hours of driving would have a lower risk of fatigue, this change in the percentage of fatigue is multiplied by the new average weekly work time and then by the average crash cost per hour of driving to obtain the value of this reduction in fatigue. For example, for the high intensity drivers, this results in a benefit of $6.00 per week (1% x 59 x $10.33) due to the reduction of the individual driver's own fatigue level. This calculation is repeated for each category of drivers (see Appendix D).

To determine the total safety benefit for the change in weekly work time for the different driver categories, the values of these two different safety effects from the change in weekly work time are summed. For example, for the high intensity drivers, this results in a total hourly benefit of $6.39 ($0.39 + $6.00) per week. We next convert this weekly value to an annual value by multiplying by 50 weeks of work per year. For example, for the high intensity drivers, this results in an annual safety benefit of $320 ($6.39 x 50) per driver in this category. We then repeat this calculation for each category of drivers (see Appendix D). The Agency seeks comment on whether our methodology for evaluating cumulative fatigue and its impact on driving performance is reasonable. The Agency also welcomes further information on the effects of cumulative fatigue, particularly in the form of scientific studies or data that would enable better evaluation of cumulative fatigue and its impact on workplace safety, driver safety performance, and productivity.

To obtain the total safety benefits for the change in weekly work time, we then multiply the annual safety benefit per driver by the total number of drivers in each category. For example, there are an estimated 304,000 (1,600,000 x 19%) high intensity drivers. Multiplying this number of drivers by the annual per driver safety benefit of $320 results in a total safety benefit for this category of drivers of $97 million. This calculation was repeated for each category of drivers, and the resulting values were summed to obtain a total safety benefit estimate of $538 million for the reduction in weekly work time. (This value is shown for Option 2 in Exhibit 6-5, for the 13 percent fatigue scenario, rounded to $540 million.)

Lastly, we calculate the total safety benefits by summing the total safety benefits resulting from the change in daily driving time ($184 million) and the total safety benefits resulting from the change in weekly work time ($538 million). This results in total safety benefits of $722 million under the median assumption for the percent fatigue involvement. (This value is shown for Option 2 in Exhibit 6-5, rounded to $720 million.)

# 5. Methodology for Valuing Health Benefits

This chapter presents our methodology for estimating the health benefits of the proposed HOS rule. These benefits result from reductions in mortality risk due to the decreases in total duty time in a day and in a week, and thus possible increases in sleep. Although there are other health impacts mitigated by reductions in long work hours and related increases in sleep, such as improvements in many chronic health problems, reduction in mortality risk was the impact that was most easily quantifiable. Another possible impact of long work hours is the foregone earnings that would result if a driver were to develop a medically disqualifying condition and reductions in driver-associated health care costs. Other than this qualitative discussion, we do not consider the possible benefits of reductions in medically disqualifying conditions or health care cost reductions in this analysis. In this chapter, we first present an overview of our methodological approach, and then we present a detailed description of the methodology for estimating the health benefits of the new rule.

## 5.1. Overview of Health Impact Methodology

As discussed in detail in the literature review on health impacts found in Appendix B, there are numerous pathways between the extreme numbers of hours per day and week allowed under existing rule and important health end points. For instance, long work hours are often linked to insufficient sleep, obesity, and cardiovascular disease. In turn, these associations with long work hours are commonly linked to other health outcomes—insufficient sleep is associated with obesity, high blood pressure, and diabetes; obesity is linked to obstructive sleep apnea (OSA), high blood pressure, cardiovascular disease, stroke, diabetes, arthritis, and other diseases. Although the biochemical basis for these pathways is generally understood, it is not possible to link the relatively small changes in work hours that will occur under the rule to changes in the health impacts to develop a quantitative estimate of the health benefits that could result from a given change in the HOS rule. The difficulty of doing quantitative analyses, though, does not mean that potential health benefits must be left aside. Instead, FMCSA believes that it is worth choosing one of the direct pathways, and building a quantitative link between HOS rule provisions and health benefits.

One of the simplest and most robust of the pathways runs from excessive hours of work, through reduced average sleep, to increases in mortality. There is a growing scientific consensus that there is a U-shaped relationship between average sleep per night and mortality rates, meaning that the further one's average sleep falls below (or above) an ideal value (of between 7 and 8 hours per night) the greater the chance of death at any given age. This sleep-mortality relationship is based on epidemiological studies, and does not in itself demonstrate causality (i.e., the epidemiology research itself does not prove that increasing sleep will cause reduced mortality). This uncertainty of causality between sleep and mortality, however, does not mean that sleep-mortality research should be ignored. There are many well-explored pathways from sleep deprivation to the kinds of health impacts that would increase mortality rates; reduced sleep produces chemical changes that have been causally related to the risk of diabetes, cardiovascular disease, inflammation (linked to cancer risk), and obesity, all of which cause increased mortality. Because of the curvature of the relationship, the impact on mortality rates per lost hour of sleep also increases the further a person falls below the ideal. This curvature means that changing average sleep makes very little difference for individuals – such as truck drivers working normal schedules – who are able to get nearly ideal amounts of sleep. On the other hand, having the chance to get slightly more sleep per night can be crucial for the health of those drivers working so hard that they are usually sleep deprived.

The data used to demonstrate this U-shaped relationship are taken from three large-scale, long-term studies [Amagai, Y., *et al*. (2004); Ferrie, J., *et al*. (2007); Tamakoshi, A. & Ohno, Y. (2004)]. For the analysis of sleep and mortality we performed a National Library of Medicine PubMed search using the following terms: sleep; rest; nap; circadian rhythm; parasomnia; insomnia; dyssomnia; hypersomnia; mortality; death; lifespan; years of life; and lifeyears. Search limits set were: search on title/abstract, publication date in past 10 years, human (non-animal) studies, English language. We also searched Google using the same set of keywords. We identified a number of studies of sleep duration and mortality. We selected only three for the final analysis because the three studies were the only ones that included information on the size and demographic makeup of the sample, the crude mortality rate (in person-years), and the confidence interval for risk of increased mortality in males and females.[18]

Amagai, Y., *et al*. (2004) followed 11,325 participants over several years in a "population-based prospective study investigating risk factors for cardiovascular diseases started in 1992. The authors report "A total of 495 deaths … were observed during the average of 8.2-year follow-up period. After adjusting for age, systolic blood pressure, serum total cholesterol, body mass index, smoking habits, alcohol drinking habits, education, and marital status, the hazard ratios (95% confidence intervals) of all-cause mortality for individuals sleeping shorter than 6 hours and 9 hours or longer were 2.4 (1.3-4.2) and 1.1 (0.8-1.6) in males, and 0.7 (0.2-2.3) and 1.5 (1.0-2.4) in females, respectively, relative to those with 7-7.9 hours sleep" [Amagai, Y., *et al*. (2004), p.124].[19]

Ferrie, J., *et al*. (2007) followed 10,308 white-collar British civil servants in a prospective cohort study, with follow-up at 12 and 17 years. The authors report finding "U-shaped associations … between sleep (≤5, 6, 7, 8, >9 hours) at Phase 1 and Phase 3 and subsequent all-cause, cardiovascular, and non-cardiovascular mortality" [Ferrie, J., *et al*. (2007), p.1659]. The "U-shaped curve" represents the frequent finding that deviations toward less sleep or more sleep than 7-8 hours increases an individual's risk of early mortality. Tamakoshi, A. & Ohno, Y. (2004) enrolled 104,010 individuals in a study of cancer risk in rural Japanese residents, followed them for approximately ten years, and found that for this sample, "Sleep duration at night of 7 hours … [showed] the lowest mortality risk" [Tamakoshi, A. & Ohno, Y. (2004), p.51].

Mapping these values on a graph results in a U-shaped curve in which 7 hours of sleep carries the lowest hazard ratio, and sleep periods of less than 7 and more than 7 hours show a

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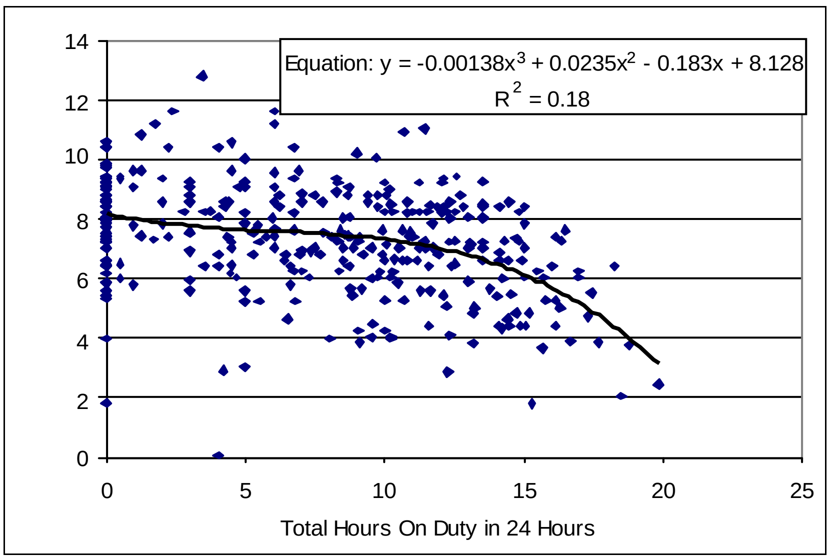
[18] A further meta-analysis published in 2010, added additional studies for a total of 1.38 million subjects and 112,000 deaths, and found a slightly higher relative risk for short sleep [Cappuccio *et al.* (2010)].

[19] For hazard ratios and odds ratios, if a confidence intervals does not include 1, the result is statistically significant. For example, an odds ratio of 2 with a confidence interval of 0.8 to 3 is not statistically significant; and an odds ratio of 1.2, with a confidence interval of 1.1 to 1.5 is significant.

progressively larger mortality hazard ratio. The process of estimating the equation is discussed in the next section.

The link from work hours to sleep is also strong. In 2002, FMCSA developed an empirical relationship between reported hours of work and measured hours of sleep for a sample of truck drivers over a period of several weeks [Balkin, T., *et al*. (2002)]. That relationship (shown in Exhibit 5-1) showed drivers getting just over 8 hours of sleep on their days off. Working a few hours on a given day had little effect on average sleep, but as the hours of work climbed, the drop in sleep per hour accelerated; at 12 hours of daily work the drivers in the sample were getting less than 7 hours of sleep, and each additional hour of work cut sleep by more than a fifth of an hour. Data on drivers from the American Time Use Survey showed little more than 6.5 hours of self-reported sleep (which is known to be overstated) at 12 hours of work, with an even steeper rate of decline per hour of extra work.[20]

**Exhibit 5-1. Effects of Duty Hours on Sleep**




Putting together the relationship of greater hours of work leading to steadily worsening sleep loss, and the relationship of sleep loss to steadily worsening mortality rates, it appears that small cuts in the maximum permissible duty hours could have health benefits that result in substantial reductions in mortality rates for the affected drivers. On the other hand, these same relationships imply that cutting hours for more typical drivers would have a much more limited benefit, because each hour of work prevented would have a smaller effect on sleep, and each added increment to sleep would have a minimal effect on mortality.

Because of the uncertainty involved in the relationships between work hours and health, and the uncertainty about baseline conditions, FMCSA is not able to produce a precise health benefit estimate. But this kind of analysis can at least show the potential magnitude of the impacts of

[20] Data extracted from 2008 American Time Use Survey database, available from the Bureau of Labor Statistics for Census Code 9130, Drivers/Sales Workers and Truck Drivers.

cutting back some of the longest work weeks. As developed below, it appears that the measurable health benefits of reducing the maximum hours of work allowed per week could well be as great as the costs, and the other pathways (which have not be included in the quantitative analysis) could add even further to these benefits.

## 5.2. DETAILED EXPLANATION OF THE ESTIMATION OF CHANGES IN DRIVERS' HEALTH

To estimate the impact of the HOS rule change on expected mortality risk, we used the four divisions of drivers discussed in Chapters 2 and 3. These four divisions categorize drivers by average hours worked and are identified as follows: moderate intensity (average weekly work time of 45 hours), high intensity (60 hours), very high intensity (70 hours), and extreme intensity (80 hours). Each group has a calculated change in hours worked, which is also described in Chapter 3. Further, for this analysis, we used low, medium, and high baseline levels of sleep to analyze the impacts of changes in hours worked on expected mortality risk to obtain a range of possible health impacts from changes in hours worked. For example, for the very high intensity group, the base hours slept for this category with a low baseline level of sleep is 6.28 hours per night, based on measured sleep for drivers in a naturalistic driving study and an assumption that these drivers were working at a high but not extreme intensity level.[21] For the higher baseline sleep assumption for this same group we entered our estimates of their average daily hours on duty into the work/sleep function based on the Walter Reed Field Study (described above) [Balkin, T., *et al*. (2002)]. The medium sleep level for this group was the average of the high and low estimates. We repeated this process for the other groups of drivers, using the predictions of the work/sleep relationship described above for the high sleep assumptions, and basing the differences between the high, low, and medium sleep levels on the differences found for the very high intensity group. Exhibit 5-2 shows our estimates on the change in work hours that would result from the HOS rule changes and our judgments (described above) on the baseline level of sleep for each category of drivers.

[21] This may be a conservative assumption as the drivers in the Hanowski *et al.* (2007) study do not appear to have been working this hard. In addition, the average is for a limited dataset and includes days off; the average across the whole dataset was a slightly lower, 6.15 hours per night including days off. Most of the drivers, however, were driving at night, which would lower overall sleep.

Exhibit 5-2. Changes in Hours Worked per Day and Baseline Levels of Sleep by Driver Group for All Options

| Driver Group | Baseline Sleep | Change in Hours Worked Per Day – Option 2 | Change in Hours Worked Per Day – Option 3 | Change in Hours Worked Per Day – Option 4 | Baseline Level of Sleep (Hours) |
|---|---|---|---|---|---|
| Extreme | Low | -1.53 | -1.53 | -1.53 | 5.87 |
| | Medium | -1.53 | -1.53 | -1.53 | 6.23 |
| | High | -1.53 | -1.53 | -1.53 | 6.59 |
| Very High | Low | -0.49 | -0.21 | -0.92 | 6.28 |
| | Medium | -0.49 | -0.21 | -0.92 | 6.64 |
| | High | -0.49 | -0.21 | -0.92 | 7.00 |
| High | Low | -0.15 | -0.02 | -0.48 | 6.55 |
| | Medium | -0.15 | -0.02 | -0.48 | 6.91 |
| | High | -0.15 | -0.02 | -0.48 | 7.27 |
| Moderate | Low | -0.04 | 0 | -0.17 | 6.66 |
| | Medium | -0.04 | 0 | -0.17 | 7.02 |
| | High | -0.04 | 0 | -0.17 | 7.38 |

The first step in estimating the change in expected mortality risk is to determine the hours of sleep gained under the rule. For this calculation, we obtain the difference between the work/sleep function evaluated at the projected hours of work per day under the HOS Option and the baseline hours worked per day. For the very high intensity group, for example, the hours projected under the proposed HOS Option was about 11.2 hours, which is equal to the baseline hours worked per day of 11.7 minus 0.5. Thus, the hours of sleep gained under the rule is expressed as follows:

$$\textit{Change in sleep} = (-0.00138 \times W^3 + 0.0235 \times W^2 - 0.183 \times W + 8.128)$$

$$- (-0.00138 \times B^3 + 0.0235 \times B^2 - 0.183 \times B + 8.128)$$

where *W* is the daily work hours after the rule change, and *B* is the daily work hours under the baseline.[22]

For the very high intensity group with low baseline sleep, for example, this calculation (carried out to an appropriate level of precision) yields an estimate of 0.091 hours of sleep gained. In turn, the total hours slept after improvement is the sum of the base hours slept per night and the total hours of improvement in sleep. For the very high intensity group with low baseline sleep, this calculation results in 6.371 hours (6.28 hours + 0.091 hours) of sleep per night under the proposed regulatory option.

The next step in the calculation of health benefits was to translate the increased sleep due to the HOS rule changes into decreased mortality risk. This relationship was estimated by regressing

[22] The equation relating hours of sleep and hours of work is $y = -0.00138x^3 + 0.0235x^2 - 0.183x + 8.128$ where $y$ is the number of hours slept and $x$ is the number of hours worked. This function was estimated using 9,781 observations of data on the numbers of hours worked and the number of hours slept for long-haul drivers.

mortality on the expected value of hours of sleep and the expected value of hours of sleep squared [Social Security Administration (2006)].[23] The statistical analyses of the Phase 1 sleep-hours data in the Ferrie study (shown in the first five rows of Exhibit 5-3, below) was complicated by the fact that the subjects' average hours of sleep was reported as categories (e.g., less than 6, 6, 7, etc.) that appeared to map to intervals (for example we assumed that a response of "6" really means 5.5 to 6.5 hours, rather than exactly 6). To convert these intervals into a point representing all of the subjects in that interval, we fitted a normal distribution to the "hours of sleep" frequency distribution presented in the first phase of the Ferrie study and obtained a mean of 6.787 hours and a standard deviation of 0.768 hours. We used this distribution to find the expected level of sleep for subjects in each interval.

To regress the mortality hazard ratios we calculated 'exph' and 'exphh,' the expected number of hours of sleep and the expected number of hours squared for each interval. Thus if the hours value is exactly N, then exph = N and exphh = N*N. We then regressed the published estimated mortality ratio versus exph and exphh (and an intercept). This gives predicted values for the mortality ratio if the hours of sleep value is exactly N (an interval from N to N) or if the hours of sleep is reported as N, but is assumed to lie inside the interval from N-0.5 to N+0.5 and comes from the fitted normal distribution. The model is shown below. The two approaches give very similar predictions, as shown in Exhibit 5-4.

Exhibit 5-3. Sleep – Mortality Risk Ratios [Ferrie, J., *et al.* (2007)]

| Sleep Hours: From | Sleep Hours: To | Frequency | Observed Mortality Ratio | Sleep Hours: Midvalue | Expected Hours: exph | Expected Hours Squared: exphh | Predicted Mortality Ratio | Standard Error |
|---|---|---|---|---|---|---|---|---|
| **Data points from Ferrie, J., *et al*. 2007:** | | | | | | | | |
| 0 | 5.5 | 587 | 1.61 | 2.75 | 5.18 | 26.94 | 1.62 | 0.06 |
| 5.5 | 6.5 | 2642 | 1.11 | 6 | 6.10 | 37.31 | 1.10 | 0.04 |
| 6.5 | 7.5 | 4884 | 1 | 7 | 6.97 | 48.68 | 0.95 | 0.05 |
| 7.5 | 8.5 | 1579 | 1.08 | 8 | 7.85 | 61.65 | 1.15 | 0.04 |
| 8.5 | 12 | 89 | 1.77 | 10.25 | 8.77 | 76.93 | 1.74 | 0.06 |
| **Fitted points assuming sleep is normally distributed:** | | | | | | | | |
| 0.5 | 1.5 | | | 1 | 1.39 | 1.95 | 7.83 | 0.66 |
| 1.5 | 2.5 | | | 2 | 2.37 | 5.63 | 5.60 | 0.44 |
| 2.5 | 3.5 | | | 3 | 3.34 | 11.16 | 3.83 | 0.27 |
| 3.5 | 4.5 | | | 4 | 4.29 | 18.42 | 2.50 | 0.14 |
| 4.5 | 5.5 | | | 5 | 5.21 | 27.21 | 1.60 | 0.06 |
| 5.5 | 6.5 | | | 6 | 6.10 | 37.31 | 1.10 | 0.04 |
| 6.5 | 7.5 | | | 7 | 6.97 | 48.68 | 0.95 | 0.05 |
| 7.5 | 8.5 | | | 8 | 7.85 | 61.65 | 1.15 | 0.04 |
| 8.5 | 9.5 | | | 9 | 8.75 | 76.66 | 1.73 | 0.06 |

[23] The equation relating mortality and the expected value of hours of sleep is $y = 11.7603 - 3.1377x + 0.2274x^2$ where $y$ represents mortality and $x$ represents the expected value of hours of sleep.

Exhibit 5-3. Sleep – Mortality Risk Ratios [Ferrie, J., *et al.* (2007)]

| Sleep Hours: From | Sleep Hours: To | Frequency | Observed Mortality Ratio | Sleep Hours: Midvalue | Expected Hours: exph | Expected Hours Squared: exphh | Predicted Mortality Ratio | Standard Error |
|---|---|---|---|---|---|---|---|---|
| 9.5 | 10.5 | | | 10 | 9.69 | 93.90 | 2.71 | 0.14 |
| 10.5 | 11.5 | | | 11 | 10.65 | 113.38 | 4.13 | 0.28 |
| 11.5 | 12.5 | | | 12 | 11.62 | 135.02 | 6.00 | 0.45 |
| **Fitted points assuming subjects sleep discrete numbers of hours:** | | | | | | | | |
| 1 | 1 | | | 1 | 1.00 | 1.00 | 8.85 | 0.76 |
| 2 | 2 | | | 2 | 2.00 | 4.00 | 6.39 | 0.52 |
| 3 | 3 | | | 3 | 3.00 | 9.00 | 4.39 | 0.32 |
| 4 | 4 | | | 4 | 4.00 | 16.00 | 2.85 | 0.17 |
| 5 | 5 | | | 5 | 5.00 | 25.00 | 1.76 | 0.07 |
| 6 | 6 | | | 6 | 6.00 | 36.00 | 1.12 | 0.04 |
| 7 | 7 | | | 7 | 7.00 | 49.00 | 0.94 | 0.05 |
| 8 | 8 | | | 8 | 8.00 | 64.00 | 1.21 | 0.04 |
| 9 | 9 | | | 9 | 9.00 | 81.00 | 1.94 | 0.08 |
| 10 | 10 | | | 10 | 10.00 | 100.00 | 3.12 | 0.18 |
| 11 | 11 | | | 11 | 11.00 | 121.00 | 4.76 | 0.33 |
| 12 | 12 | | | 12 | 12.00 | 144.00 | 6.85 | 0.53 |

Although the fitted normal distribution to the hours of sleep is standard statistical modeling (assuming we are correct to treat a response of 6 as meaning from 5.5 to 6.5, etc.), the quadratic regression analysis is highly approximate because it does not take into account how the covariates affect the estimated mortality ratios. However, it should be a good approximation.

The following model was estimated for the distribution of hours of sleep, assuming "6" means between 5.5 and 6.5 hours, and so forth. This model uses the sleep frequency distribution presented in Phase 1 of the study and best-fitting normal distribution.

> Normally distributed:
> Mean 6.787198
> Standard Deviation 0.76828
>
> Regression model for mortality hazard ratio, assuming:
> Hazard ratio = a + b*exph + c*exphh + error
> Exph = expected value of hours of sleep
> Exphh = expected value of hours of sleep squared
> Error is normally distributed with mean zero

| Parameter | Value | Standard Error | P-value |
|---|---|---|---|
| a | 11.76028 | 1.0430 | 0.0078 |
| b | -3.13766 | 0.3067 | 0.0094 |
| c | 0.227359 | 0.0219 | 0.0092 |

For example, if the hours of sleep is exactly 7, then exph = 7 and exphh = 49 and so the predicted hazard ratio = 0.937228
If the hours of sleep is the interval from 6.5 to 7.5, then:
Exph = 6.971673
Exphh = 48.68249
Predicted hazard ratio = 0.95392

Exhibit 5-4 shows the shape of this function, along with confidence bounds based on the regression.

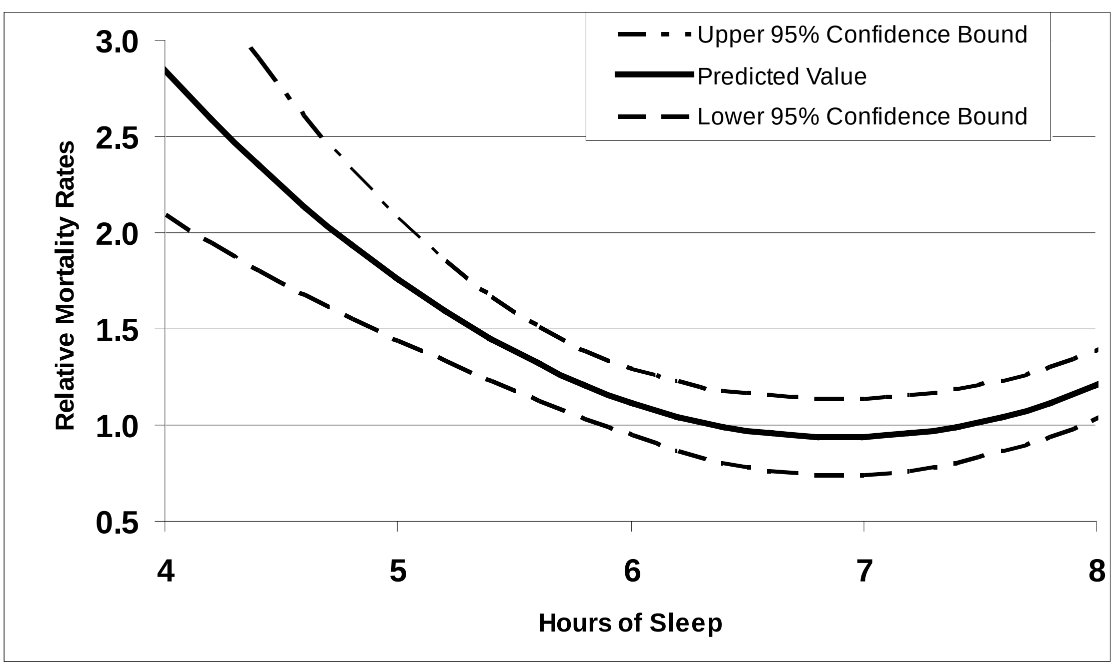
Similar to the sleep function discussed above, the change in mortality can then be estimated by calculating the difference between the sleep/mortality function evaluated at the projected hours of sleep per day under the HOS Option and the baseline hours slept per day, shown below:

$$\textit{Change Mortality} = (-3.138 \times S^2 + 0.227 \times S + 11.706)$$

$$- (-3.138 \times B^2 + 0.227 \times B + 11.706)$$

where S is the hours of sleep under the HOS Option and B is the hours of sleep under the baseline.

**Exhibit 5.4. Sleep Mortality Function**



To see more concretely how these functions are used to quantify and monetize the reductions in mortality associated with changes to the HOS rules, it helps to follow through a specific example. The remainder of this section traces through the effects of the first of the three regulatory alternatives (Option 2) for one group of drivers (the very high intensity group) and one assumption about baseline sleep (low). The application of the method, though, is the same for all options, intensities, and baseline sleep levels. For example, under Option 2, for the very high intensity group with low sleep, the value of the change in mortality from the equation above is approximately 2.37 percent.

We calculated the effect of a change in mortality rates on life expectancy using information on mortality rates and life expectancy for a cross-section of ages that might be affected by a change in sleep. Actuarial data on a hypothetical population of 100,000 male infants show that over 98,000 can be expected to survive to 21, the age at which they could become interstate truck drivers.[24] From that point, individuals at each age have a projected life expectancy, and a mortality rate (i.e., chance of dying before reaching their next birthday). More formally, for each age *i* from 21 to a maximum age (e.g., 110), there is a remaining population $P_i$, with morality rate $M_i$, and a life expectancy $e_i$. $P_i$ can be expressed as $P_{i-1}$ x $(1- M_{i-1})$. The remaining population at each successive age is, thus, marginally smaller than at the preceding age due to the small percentage dying each year.

If an additional individual dies at age *i*, the expected change in life years in the population is equal to the life expectancy for an individual of that age. In other words, if an individual dies at age *i*, the loss of expected life years equals $e_i$. For simplicity, we assume that a mortality change of *x* percent would apply equally across the population at all ages. Thus, at each age, the number of deaths would rise from $P_i$ x $M_i$ to $P_i$ x ($M_i$ x (1 + $x$%)), for an increase of $P_i$ * ($M_i$ x $x$%), and the expected life years lost for each age cohort would be $P_i$ * ($M_i$ x $x$%) * $e_i$. Summing across age cohorts gives $\sum_{i=21}^{i=110}[P_i \times (M_i \times x\%) \times e_i]$, or, equivalently, $x\% \times \sum_{i=21}^{i=110}[P_i \times M_i \times e_i]$ as the total years lost out of an initial population of 98,344. Thus, the total years lost for a percentage increase in mortality is proportional to the increase, and is equal to the initial population times the average life years lost for those dying in the baseline. Given the actuarial data for American men, we found that each 1 percent increase in mortality is associated with the loss of an expected 11,365 years of life for an initial population of 98,344. To find the lost life years per individual, we divided the expected loss of 11,365 life years by the initial population of 98,344, obtaining 0.1156 years (that is, almost a month and a half) per 1 percent increase in mortality. Thus, a reduction in mortality of 2.37 percent would be associated with an increased life expectancy of 2.37 x 0.1156, or 0.2744 years.

The next step in calculating the health benefits of the HOS rule is to monetize the estimated changes in mortality risk. The valuation of increased safety and health—or of reductions in mortality—under the proposed rule can be accomplished using the concept of a VSL. A VSL is used to place a monetary value on incremental mortality risk reduction. VSL is the monetary value of a mortality risk reduction that would prevent one *statistical* (as opposed to an identified)

[24] This analysis focuses on males because they currently constitute a large majority of truck drivers.

death [Jones-Lee, M.W. (2004)]. From the VSL, we can calculate a VSLY, which is the annualized value of a VSL over an individual's expected remaining years.

After calculating the expected mortality improvement, we can monetize this improvement by using an estimate for the VSLY. Using DOT's current estimated VSL of $6 million [Szabat, J. (2009)], and assuming a discount rate of 3 percent and an assumption of an average of 37 years of life remaining for drivers (assuming a typical driver is 40 years old), the VSLY is calculated as $270,670. Then, using the estimate of the years of life gained per driver for the different categories of drivers, we can estimate the value of years gained by multiplying the calculated VSLY by the years gained per driver per career. For example, for the very high intensity group with a low baseline level of sleep, this resulted in a value of years gained of $74,285 ($270,670 x 0.2744 years) per driver per career. We then repeated this calculation for each driver category and the different baseline levels of sleep.

The penultimate step in the calculation of health benefits was to calculate the value of improvement in mortality per year of improved sleep by dividing the total value of years gained by the average length of a driver's career (35 years). This step is taken on the assumption that the full improvement in life expectancy will occur only for drivers who sleep more over their entire careers, and that sleeping more for only a single year will have a proportionately smaller benefit.[25] For the very high intensity group with a low baseline level of sleep, for example, this calculation yielded a gain per year of $2,122 in terms of reduced mortality.

Finally, we calculate the total value of improvements to mortality by multiplying the per-driver value of improvement in mortality per year by the number of drivers. For example, for the very high intensity group with a low baseline level of sleep, the total value of improvements in mortality was approximately $340 million ($2,122 x 160,000 drivers). We then repeated this calculation for each driver category and the different baseline levels of sleep, and summed them across the categories.

The total value for the low baseline sleep group for all intensity categories was $1.484 billion (shown in Exhibit 6-11, rounded to $1,480 million), while the total value for the medium baseline sleep group was $689 million (shown in Exhibit 6-11, rounded to $690 million). Finally, the total value for the high baseline level of sleep group for all intensity categories was -$105 million (shown in Exhibit 6-11, rounded to negative $110 million), indicating that the additional sleep would be detrimental to driver health. This negative value is the result of the U-shaped relationship between average sleep per night and mortality rates mentioned above. Although our analysis shows a negative health benefit for drivers with a high baseline level of sleep, we do not believe that these negative benefits would be realized because drivers are likely to choose other activities rather than sleeping if they are getting enough sleep already. We have included the negative benefits in our analysis to be consistent with our assumptions regarding the other scenarios.

[25] A driver near the end of his or her career, for example, might gain relatively little, but only because the restriction on work hours would affect him or her for relatively few years. The benefit per year of work, though, is potentially the same as for other drivers.

## 5.3. UNQUANTIFIED HEALTH BENEFITS

In addition to the quantified and monetized benefits discussed above, there may be other health benefits that shorter work days and weeks could produce. Research indicates that the metabolic and endocrine disruptions associated with short sleep time and long work hours are significantly related to obesity [Van Cauter, E. & Knutson, K, (2008) and Di Milia, L. & Mummery, K. (2009)]. Obesity is in turn associated with higher incidences of diabetes, cardiovascular diseases, hypertension, and OSA [Mokdad, A.H., *et al*. (2001)]. Each of these medical conditions imposes costs on drivers who suffer from them and affects the quality of their lives. Sedentary work alone is also associated with obesity and mortality impacts [Katzmarzyk, P.T., *et al*. (2009)].

Research on the health and health costs for CMV drivers found that drivers are both heavier for their height and less healthy than the adult male population of workers. Drivers are far more likely than the adult worker population as a whole to be obese. Exhibit 5-5 presents the distribution of drivers by weight category and the incidence of health conditions for each weight group from a study of 2,950 CMV drivers [Martin, B.C., *et al*. (2009)]. (The national statistics for adult males include men over 70, who may have higher incidences of some conditions than the younger working population.)

We have not attempted to quantify every type of health benefit that may accrue to drivers who have more time off. First, FMCSA does not have dose-response curves that it can use to associate sleep time to mitigation or exacerbation of the various health impacts other than sleep loss itself. Second, FMCSA has no basis for estimating the extent to which drivers who have an extra hour a day off duty or extra hours per week would use that time to exercise. Third, many of the health impacts are linked to obesity; given the difficulty most people have in losing weight, it would be unjustifiably optimistic to attempt to estimate the degree of potential weight loss.

Exhibit 5-5. Driver Health Conditions by Weight Category

| N = 2,950 | Percent in Weight Category | Presence of at Least One Health Risk Factor | Hypertension | Diabetes | High Cholesterol |
|---|---|---|---|---|---|
| Normal Weight | 13% | 26% | 21% | 5% | 11% |
| Overweight | 30% | 39% | 31% | 10% | 17% |
| Obese | 55% | 59% | 51% | 21% | 26% |
| Overall | 5% | 48% | 41% | 16% | 21% |
| National Adult Male | | | 31.80% | 10.9%(7.4% diagnosed) | 15.60% |

The health impacts that flow from inadequate sleep and long stretches of sedentary work are, however, significant: they cause serious health conditions that may shorten a driver's life and increase healthcare costs. In addition, some studies have linked obesity to increased crash risks, including a recent analysis of the Hanowski, R.J., *et al*. (2007) data, which found that obese CMV drivers were between 1.22 and 1.69 times as likely to drive while fatigued, 1.37 times more likely to be involved in a safety-critical event, and at 1.99 times greater risk of being above the fatigue threshold as measured by eye closure when driving [Wiegand, D.M., *et al*. (2009)].

# 6. Results

This chapter presents the results of the economic analysis of the HOS rule changes. First, we summarize the costs of Options 2 through 4. As discussed previously, Options 2 through 4 limit daily duty time to 13 (from 14 hours), require at least one break during the duty day (none is currently required), and limit the use of the 34-hour restart provision to once every 168 hours with at least 2 nights off duty. Options 2 through 4 differ only in driving time allowed between 10-hour breaks. Option 2, one of the alternatives being proposed, limits allowable daily driving to 10 hours, the driving limit that existed prior to the 2003 rule. Option 3, the other alternative being proposed, retains the 11 hours of driving allowed under the current rule. Option 4 allows only 9 hours of driving, or 1 hour less than Option 2.

The costs of Options 2 through 4 consist of annual operational costs that result from lost productivity and one-time rule training and reprogramming costs which drivers and carriers incur as a result of the rule changes. These two cost components are summed to obtain the total costs for the options. Next, the benefits of the Options 2 through 4 are presented. The benefits consist of safety benefits from the reduction in fatigue-related crashes and health benefits from drivers working long hours potentially getting more sleep and reducing their mortality risk. These benefit categories are summed to obtain the total benefits of the options. The chapter then presents the net benefits of Options 2 through 4 by subtracting total costs from the total benefits. Next, we briefly discuss the limitations of our analysis. Next, the chapter analyzes the sensitivity of the net benefit estimates for the options to changes in the VSL. The chapter then presents a summary of the results for the options. We next discuss the mode shift implications of the options and the implications of the options on the number of drivers. We then conclude the chapter with a discussion of the safety impacts of new drivers and mode shifts.

In brief, this chapter shows annualized costs of about $1 billion for Option 2, about $500 million for Option 3, and over $2 billion for Option 4. These costs can be compared to annual safety and health benefits estimated to range from below $300 million to over $2.4 billion for Option 2, from over $300 million to below $1.8 billion for Option 3, and from negative $10 million to over $3.6 billion for Option 4, under different baseline assumptions. Net benefits, as a result, are likely to be positive, but could range from a negative $750 million per year to more than a positive $1.4 billion per year for Option 2, from a negative $190 million per year to more than a positive $1.2 billion per year for Option 3, and from a negative $2.3 billion to more than a positive $1.3 billion for Option 4. The wide ranges in estimates of benefits and net benefits are a consequence of the difficulty of measuring fatigue and fatigue reductions, which are complex and often subjective concepts, in an industry with diverse participants and diverse operational patterns. Still, it seems clear that the benefits for Options 2 through 4 could easily be substantial, and are on the same scale as the costs for these options. The costs, for their part, are large in absolute terms but minor when compared to the size of the industry: the costs of Option 2 (about $1 billion per year) is only half of 1 percent of revenues, the costs for Option 3 (about $500 million per year) is only one quarter of 1 percent of revenues, and the costs for Option 4 (about $2 billion per year) is only 1 percent of revenues in the for-hire long-haul segment of the industry. These total annual costs are an even smaller fraction of revenues of the long-haul segment as a whole.

Compared to the other options that were analyzed, Option 4 would have roughly twice the costs of Option 2 and over four times the cost of Option 3. In keeping with their relative stringencies, Option 3 has lower, and Option 4 has higher, projected benefits than Option 2. Option 3's calculated net benefits appear likely to be somewhat higher than the net benefits of Option 2 under some assumptions about baseline conditions. Option 4's substantially larger costs, on the other hand, did not appear to be justified by its generally higher range of benefits. In addition to the analyses presented in this chapter, the Agency has conducted a series of analyses to evaluate the costs and benefits of the individual components of this rule. These ancillary analyses can be found in Appendix C of this regulatory evaluation, and include examining the costs and benefits of each rule component for varying levels of baseline fatigue involvement and discount rates.

## 6.1. COSTS

The costs of Options 2 through 4 consist of operational changes, which accrue annually from losses in productivity when drivers adjust to the new HOS rule provisions, and from training and reprogramming costs, which drivers and carriers incur one time to adjust to the new HOS rule provisions. These cost categories are then summed to estimate the total costs of the options.

### *6.1.1. Operational Costs*

The methodology for estimating the costs of operational changes that result from the new HOS rule provisions was described in Chapter 3. As described earlier, the new HOS rule provisions affect drivers differently, based on the intensity of their work schedule. Costs were thus estimated separately for different categories of drivers. As discussed in Chapter 3, costs of operational changes result from three effects of the new HOS rule: reduction of daily work hours, reduction of weekly work hours, and reduction in work time due to the restart provision. We have not estimated the effects of several less important rule provisions, for reasons discussed in Section 6.5. Exhibits 6-1 through 6-3 present the results of our estimation of the costs of each of these three effects for each category of drivers for Options 2 through 4. The costs of these effects are then totaled for each category of drivers, and then summed across all drivers to obtain the total cost of operational changes for Option 2 through 4. As shown in Exhibits 6-1 through 6-3, the total annual cost is $990 million for Option 2, $480 million for Option 3, and $2.270 billion for Option 4 (measured, as are all of the monetary values in this RIA, in 2008$).

Exhibit 6-1. Costs of Operational Changes by Allowed Daily Hours of Driving for Option 2 (Millions 2008$)

| Driver Category | Reduction of Daily Work Hours | Reduction of Daily Driving Hours | Reduction due to Restart Provisions | Total |
|---|---|---|---|---|
| Moderate | $0 | $160 | $0 | $160 |
| High | $10 | $150 | $0 | $170 |
| Very High | $50 | $170 | $50 | $270 |
| Extreme | $120 | $100 | $170 | $390 |
| Total | $190 | $590 | $210 | $990 |

Note: Totals do not add due to rounding.

Exhibit 6-2. Costs of Operational Changes by Allowed Daily Hours of Driving for Option 3 (Millions 2008$)

| Driver Category | Reduction of Daily Work Hours | Reduction of Daily Driving Hours | Reduction due to Restart Provisions | Total |
|---|---|---|---|---|
| Moderate | $0 | $0 | $0 | $0 |
| High | $10 | $0 | $0 | $10 |
| Very High | $50 | $0 | $50 | $100 |
| Extreme | $120 | $0 | $240 | $370 |
| Total | $190 | $0 | $290 | $480 |

Note: Totals do not add due to rounding.

Exhibit 6-3. Costs of Operational Changes by Allowed Daily Hours of Driving for Option 4 (Millions 2008$)

| Driver Category | Reduction of Daily Work Hours* | Reduction of Daily Driving Hours | Reduction due to Restart Provisions | Total |
|---|---|---|---|---|
| Moderate | | $710 | $0 | $710 |
| High | | $550 | $0 | $550 |
| Very High | | $510 | $50 | $560 |
| Extreme | | $350 | $100 | $450 |
| Total | | $2,120 | $150 | $2,270 |

Note: Totals do not add due to rounding.
* The costs associated with the limit on daily driving hours are combined with the much greater costs of reduced daily driving hours for this option.

### *6.1.2. Training and Reprogramming Costs*

Drivers and carriers also incur costs due to the need for drivers to be trained in the new rule provisions and for carriers to reprogram their equipment. Based on the judgment of FMCSA's experts on enforcement training, drivers would need a total of 2 hours of training to learn the new HOS rule provisions. To estimate the cost of this effort, we used U.S. Bureau of Labor Statistics (BLS) truck driver wage data, which showed 3.34 percent annual hourly wage increases for the period from 1998 through 2007.[26] We applied this growth rate three times to the 2007 BLS weighted average hourly truck driver wage rate of $16.58 to arrive at a 2010 hourly rate of $18.29. We then multiplied the 2010 wage rate by 1.31 to obtain a loaded average hourly rate of $23.96 (wages plus fringe benefits). The 2-hour training course thus resulted in a cost of $47.92 per driver.

Carriers would incur additional one-time costs for software reprogramming and other transition costs. These costs were estimated using information obtained from the HOS listening sessions conducted in various locations in early 2010. Based on information from these sessions, we

[26] http://data.bls.gov:8080/oep/servlet/oep.noeted.servlet.ActionServlet

assumed that the total one-time training, reprogramming, and other transition costs were about $200 per driver (including the approximately $48 per driver cost discussed above). To obtain an industry-wide cost, we multiplied this per-driver cost of $200 by the total number of drivers (1,600,000) to obtain a total one-time cost to the industry of approximately $320 million. We amortized this cost over 10 years using a 7-percent discount rate to obtain an annualized cost of roughly $40 million.

### *6.1.3. Total Costs*

The next step was to sum the annual and one-time costs to obtain a total cost of the new HOS rule for Options 2 through 4. As shown below in Exhibit 6-4, summing the different cost components resulted in a total cost of $1.030 billion for Option 2, $520 million for Option 3, and $2.310 billion for Option 4. Though these costs are estimated using impacts on industry productivity, they would most likely be passed along as increases in freight transportation rates, and then ultimately to consumers in increased prices for the goods that are transported by truck. As mentioned in Chapter 3, however, these prices increases would be relatively small even for a rule imposing substantial total annual costs: a total annual increase in freight costs of $1.03 billion, $520 million, or $2.31 billion would be on the order of $9, $4, and $20 per household per year, respectively.

Exhibit 6-4. Total Costs for All Options (Millions 2008$)

| Cost Category | Option 2 | Option 3 | Option 4 |
|---|---|---|---|
| Reduction of Daily Work Hours | $190 | $190 | * |
| Reduction of Daily Driving Hours | $590 | $0 | $2,120 |
| Reduction due to Restart Provisions | $210 | $290 | $150 |
| Training and Reprogramming Cost | $40 | $40 | $40 |
| **Total Costs** | **$1,030** | **$520** | **$2,310** |

* The costs associated with the limit on daily driving hours are combined with the much greater costs of reduced daily driving hours for this option

## 6.2. BENEFITS

Next, we estimated the total benefits of Options 2 through 4 by summing the two categories of benefits arising from the new rule: safety benefits and health benefits.

### *6.2.1. Safety Benefits*

As described in Chapter 4, safety benefits arise from the reduction in the probability of fatigue-related crashes by long-haul drivers. This crash reduction is thought to arise from two effects: reduced acute TOT effects from restrictions in daily driving time, and reduced cumulative TOT effects from reductions in weekly work time. The monetary value of each of these effects was estimated under three different assumptions of the baseline level of fatigue involvements in crashes: 7 percent, 13 percent, and 18 percent. The total benefits resulting from improvements in the safety of long-haul drivers for Options 2 through 4 are shown below in Exhibits 6-5 though 6-7.

Exhibit 6-5. Safety Benefits (Dollars) for Option 2 (Millions 2008$)

| Assumed Percent of Crashes Due to Fatigue | Benefits Due to Reduced Acute Time on Task Effect | Benefits Due to Reduced Cumulative Time on Task Effect | Total Benefits Due to Reduced Crashes |
|---|---|---|---|
| 7 percent | $100 | $290 | $390 |
| 13 percent | $180 | $540 | $720 |
| 18 percent | $250 | $740 | $1,000 |

Note: Totals do not add due to rounding.

Exhibit 6-6. Safety Benefits (Dollars) for Option 3 (Millions 2008$)

| Assumed Percent of Crashes Due to Fatigue | Benefits Due to Reduced Acute Time on Task Effect | Benefits Due to Reduced Cumulative Time on Task Effect | Total Benefits Due to Reduced Crashes |
|---|---|---|---|
| 7 percent | $10 | $220 | $230 |
| 13 percent | $20 | $410 | $430 |
| 18 percent | $20 | $570 | $590 |

Note: Totals do not add due to rounding.

Exhibit 6-7. Safety Benefits (Dollars) for Option 4 (Millions 2008$)

| Assumed Percent of Crashes Due to Fatigue | Benefits Due to Reduced Acute Time on Task Effect | Benefits Due to Reduced Cumulative Time on Task Effect | Total Benefits Due to Reduced Crashes |
|---|---|---|---|
| 7 percent | $260 | $400 | $660 |
| 13 percent | $490 | $740 | $1,220 |
| 18 percent | $670 | $1,020 | $1,690 |

Note: Totals do not add due to rounding.

In addition to estimating the monetary value of the improvements in safety, we also estimated the lives saved due to the safety improvements. To estimate lives saved, we assumed that the proposed rule would have the same relative effect on fatalities as on all crash damages caused by heavy trucks. The resulting estimates of the total lives saved for Options 2 through 4 are shown in Exhibits 6-8 though 6-10.

Exhibit 6-8. Safety Benefits (Lives Saved) for Option 2

| Assumed Percent of Crashes Due to Fatigue | Lives Saved Due to Reduced Acute Time on Task Effect | Lives Saved Due to Reduced Cumulative Time on Task Effect | Total Lives Saved Due to Reduced Crashes |
|---|---|---|---|
| 7 percent | 7 | 19 | 26 |
| 13 percent | 12 | 36 | 48 |
| 18 percent | 17 | 50 | 66 |

Note: Totals do not add due to rounding.

Exhibit 6-9. Safety Benefits (Lives Saved) for Option 3

| Assumed Percent of Crashes Due to Fatigue | Lives Saved Due to Reduced Acute Time on Task Effect | Lives Saved Due to Reduced Cumulative Time on Task Effect | Total Lives Saved Due to Reduced Crashes |
|---|---|---|---|
| 7 percent | 1 | 15 | 15 |
| 13 percent | 1 | 27 | 29 |
| 18 percent | 2 | 38 | 39 |

Note: Totals do not add due to rounding.

Exhibit 6-10. Safety Benefits (Lives Saved) for Option 4

| Assumed Percent of Crashes Due to Fatigue | Lives Saved Due to Reduced Acute Time on Task Effect | Lives Saved Due to Reduced Cumulative Time on Task Effect | Total Lives Saved Due to Reduced Crashes |
|---|---|---|---|
| 7 percent | 17 | 26 | 44 |
| 13 percent | 32 | 49 | 81 |
| 18 percent | 45 | 68 | 113 |

Note: Totals do not add due to rounding.

### *6.2.2. Health Benefits*

Next, we estimated the total benefits due to improvements in driver health, as described in Chapter 5. The health benefits of Options 2 through 4 were estimated for three different levels of baseline sleep by drivers (shown in Exhibit 6-11). For the assumption of a high level of baseline sleep for Options 2 and 4, it is interesting to note that the benefits are negative, indicating that it is not beneficial for individuals to get additional sleep if they are already getting adequate sleep. As discussed in Chapter 5, we do not believe that the negative benefits for drivers with a high baseline level of sleep would be realized, but we include them to keep the analysis consistent with our other scenarios. In addition, it is unlikely that drivers in the extreme and very high groups, who are principally affected by the rule changes, would be able to obtain the amount of sleep projected for the high sleep category. Even drivers working 50 to 60 hours a week sleep less on many work days than the projected high sleep amounts of 6.59 for extreme drivers and 7 hours for drivers with very high intensity schedules. For any of these drivers who are driving at night, the estimated baseline sleep is likely to be substantially less across all categories.

Exhibit 6-11. Health Benefits for All Options
(Millions 2008$)

| Assumed Baseline Amount of Nightly Sleep | Total Benefits Due to Increased Sleep – Option 2 | Total Benefits Due to Increased Sleep – Option 3 | Total Benefits Due to Increased Sleep – Option 4 |
|---|---|---|---|
| Benefits with Low Sleep | $1,480 | $1,190 | $1,990 |
| Benefits with Medium Sleep | $690 | $650 | $660 |
| Benefits with High Sleep | -$110 | $100 | -$670 |

### *6.2.3. Total Benefits*

The next step was to sum the safety and health benefits to obtain the total benefits of the new HOS rule. Exhibit 6-12 through 6-14 present the results of summing the categories of benefits under different assumptions for the baseline fatigue level and the baseline level of nightly sleep by drivers for Options 2 through 4.

Exhibit 6-12. Total Benefits for Option 2 (Millions 2008$)

| Assumed Baseline Percent of Crashes Due to Fatigue | Assumed Baseline Amount of Nightly Sleep | | |
|---|---|---|---|
| | Low Sleep | Medium Sleep | High Sleep |
| 7 percent | $1,870 | $1,080 | $280 |
| 13 percent | $2,210 | $1,410 | $620 |
| 18 percent | $2,480 | $1,690 | $890 |

Exhibit 6-13. Total Benefits for Option 3 (Millions 2008$)

| Assumed Baseline Percent of Crashes Due to Fatigue | Assumed Baseline Amount of Nightly Sleep | | |
|---|---|---|---|
| | Low Sleep | Medium Sleep | High Sleep |
| 7 percent | $1,420 | $880 | $330 |
| 13 percent | $1,620 | $1,080 | $530 |
| 18 percent | $1,790 | $1,240 | $700 |

Exhibit 6-14. Total Benefits for Option 4 (Millions 2008$)

| Assumed Baseline Percent of Crashes Due to Fatigue | Assumed Baseline Amount of Nightly Sleep | | |
|---|---|---|---|
| | Low Sleep | Medium Sleep | High Sleep |
| 7 percent | $2,650 | $1,320 | -$10 |
| 13 percent | $3,210 | $1,880 | $560 |
| 18 percent | $3,680 | $2,350 | $1,030 |

## 6.3. NET BENEFITS

Next, we calculated the net benefits of Options 2 through 4 by subtracting the total estimated costs from the total estimated benefits for these options. The resulting net benefit estimates for Options 2 through 4 are shown in Exhibits 6-15 through 6-17 for the different assumed baseline levels of fatigue involvement in crashes and sleep. The net benefits of Option 2 are negative for all three baseline fatigue levels when a high baseline level of sleep for drivers is assumed. The net benefits of Option 3 are negative for the 7 percent baseline fatigue level when a high baseline level of sleep for drivers is assumed. The net benefits for Option 4 are negative for all three baseline fatigue levels when a high baseline level of sleep for drivers is assumed, and are negative for the 7 and 13 percent baseline fatigue levels when a medium baseline level of sleep is assumed. For all three options, the net benefits are positive for all three baseline fatigue levels using the assumption of a low level of baseline sleep for drivers.

Exhibit 6-15. Net Benefits for Option 2 (Millions 2008$)

| Assumed Percent of Crashes Due to Fatigue | Assumed Amount of Nightly Sleep | | |
|---|---|---|---|
| | Low Sleep | Medium Sleep | High Sleep |
| 7 percent | $840 | $50 | -$750 |
| 13 percent | $1,170 | $380 | -$410 |
| 18 percent | $1,450 | $660 | -$140 |

Exhibit 6-16. Net Benefits for Option 3 (Millions 2008$)

| Assumed Percent of Crashes Due to Fatigue | Assumed Amount of Nightly Sleep | | |
|---|---|---|---|
| | Low Sleep | Medium Sleep | High Sleep |
| 7 percent | $900 | $360 | -$190 |
| 13 percent | $1,100 | $560 | $10 |
| 18 percent | $1,260 | $720 | $180 |

Exhibit 6-17. Net Benefits for Option 4 (Millions 2008$)

| Assumed Percent of Crashes Due to Fatigue | Assumed Amount of Nightly Sleep | | |
|---|---|---|---|
| | Low Sleep | Medium Sleep | High Sleep |
| 7 percent | $340 | -$990 | -$2,320 |
| 13 percent | $900 | -$420 | -$1,750 |
| 18 percent | $1,370 | $50 | -$1,280 |

## 6.4. LIMITATIONS OF THE ANALYSIS

This analysis was, of necessity, limited in scope to calculations of what FMCSA judged to be the most important effects of the most important provisions of the rule changes under consideration.

As mentioned above, ideally, the agency would have data to measure crash risk along all of the dimensions for which regulations are proposed. Because the agency has been not been able to gather such data, it has based its analysis, in significant part, on share of crashes that are fatigue-coded. The agency recognizes that using share of crashes that are fatigue-coded could have two possible problems: Accident inspectors may be more likely to code crashes as fatigue-related if the driver has been on the road longer. Also, the share of crashes that are coded as fatigue-related may conceivably increase simply because the share of crashes caused by other factors goes down. There could be no increase in the risk of a fatigue-related crash (the central question), but an increase in the share of fatigue-related crashes. The Agency has little evidence that either of these factors are a significant problem.

Nonetheless, while the data are not as complete as FMCSA would like them to be, the Agency aimed to limit, to the extent possible, the likelihood that drivers will be fatigued, either when they come on duty or during or at the end of a working period. Safety benefits are based on this reduction in fatigue and an associated reduction in fatigue-coded crashes.
One provision that was not explicitly modeled was the prohibition on driving if more than 7 hours have elapsed since an off-duty break of at least 30 minutes. The incremental costs of this provision are likely to be inconsequential because most drivers are likely to be taking breaks of at least 30 minutes already and because of its overlap with the 13-hour limit on on-duty time within the driving window. The benefits of this provision also overlap with the benefits of the 13-hour limit, though there could also be additional, unquantified, benefits from the restorative effects of taking a break in the middle of long stretches of driving. FMCSA welcomes input through the comment process on the magnitude of these potential benefits, particularly in the form of data sets and scientific studies.

As discussed in Sections 4.2 and 4.3, data limitations and the complexity of fatigue processes create significant uncertainty about the effects of long driving hours on crash risks. After considering many studies and possible approaches, the analysis uses a TOT function based on the increase in the percentage of fatigue-coded crashes as driving hours increase. This approach has the weakness that the increasing percentage could be due to falling risks of non-fatigue-coded crashes, but as discussed in Section 4.3 that weakness is likely to be of theoretical concern only. A more serious question arises from the fact that the determination of fatigue involvement is somewhat subjective, and could be influenced by knowledge of drivers' schedules or the time of day on the part of the person coding the factors related to a crash. The TOT function used in the analysis is, nonetheless, very moderate in magnitude compared to those found by many TOT studies, and FMCSA considers it to be unlikely to be overstated.

We did not attempt to compute the costs or safety impacts of the provision allowing an occasional 16-hour driving window. This provision would offer both costs and cost savings to carriers. Because its use would delay the start of the next work shift, it would reduce the expected hours available for working in a week. Those costs can be assumed to be offset, though, by the flexibility the provision would afford to the driver. Because the use of this provision is voluntary, carriers would want to use it only when they expect it to improve their productivity. The extent to which it would be used is extremely difficult to estimate, because it would depend on the balancing of costs and cost savings as seen by the carriers. Its effects on safety benefits are even more difficult to estimate: though it allows drivers to be behind the wheel later in their work days, which by itself could increase fatigue, it also gives drivers the chance to rest or even sleep at times when they most need that rest. Those extra occasions for rest could well offset the longer driving window. Furthermore, to the extent that the provision reduces total work hours by delaying the start of the next work shift, it is likely to reduce fatigue and crashes in the following week.

We were also unable to account for all of the benefits of the 2-night requirement of the restart provision. The additional costs of this requirement have been included, along with health and safety benefits of the reduction in work hours. The main point of the provision, though, is to address the extra need for rest for drivers on a night schedule. Those circadian-related benefits could not be incorporated at the time this analysis was conducted.

In some previous analyses of the benefits of changes in HOS rule provisions, the Agency has calculated the safety consequences of hiring new drivers who are less experienced than the average existing driver. Because less experienced drivers have higher crash rates, the previous analyses found a small increase in crashes that offset part of the safety benefits of more restrictive HOS rule provisions. Those earlier analyses also found, however, an additional safety benefit from the shift of a small fraction of long-haul freight from trucks to rail, that results from more stringent HOS rule provisions. Because these two effects were found not only to be small, but to cancel each other out almost exactly, FMCSA did not consider them sufficiently important to include in this analysis. More detail on these analyses is presented in Sections 6.9 and 6.10 below.

Two other effects of the daily driving restriction are possible, but could not be analyzed with available information. First, for Options 2 and 4, limits of 10 or 9 hours of driving in a day could reduce the number of shipments that can be delivered in a single day with a single driver; and, for some shipments, this change in service characteristics could have a cost that is not included. FMCSA welcomes input, particularly in the form of studies or data sets, on the percentage of shipments with these characteristics, the incremental costs of using team or relay drivers to overcome this limitation, and the potential for ameliorating this limitation by expedited loading or unloading. Data on the experience of shippers and carriers when the daily driving limit was extended from 10 to 11 hours in 2004 would be particularly welcome.

Lastly, no attempt was made to estimate effects on congestion; total driving is likely to drop slightly because higher rates for shippers are likely to lead to a small shift from truck to rail, while the requirement to take 2 nights off before restarting will in some cases encourage slightly more driving during the day.

## 6.5. Sensitivity of Net Benefits to Changes in VSL

One form of sensitivity analysis we performed was to examine the sensitivity of the net benefits of Options 2 through 4 to different assumed VSL estimates. Guidance provided by DOT in 2009 suggested that a VSL of $5.8 million be used for regulatory analyses, and that sensitivity analyses be performed using a lower-bound VSL of $3.2 million and an upper-bound VSL of $8.4 million. Later in 2009, DOT suggested that the $5.8 million value should be raised to $6.0 million, but did not provide further guidance on the lower- and upper-bound VSLs [Szabat, J. (2009)]. For this analysis, we scaled up the original lower- and upper-bound VSLs suggested by DOT to match the scaling up of the mean value from $5.8 million to $6.0 million. This resulted in a new lower-bound VSL of $3.3 million ($3.2 million x 1.034) and a new upper-bound VSL of $8.7 million ($8.4 million x 1.034). We calculated the net benefits of Options 2 through 4 using the different VSL assumptions for the three different baseline sleep assumptions and an assumption of a 13 percent baseline fatigue level, as shown below in Exhibits 6-18 through 6-20.

Exhibit 6-18. Net Benefits for Option 2 for Different VSL Assumptions (Millions 2008$)

| Assumed VSL | Assumed Amount of Nightly Sleep | | |
|---|---|---|---|
| | Low Sleep | Medium Sleep | High Sleep |
| Lower-bound VSL | $240 | -$200 | -$640 |
| Mean VSL | $1,170 | $380 | -$410 |
| Upper-bound VSL | $2,110 | $960 | -$190 |

Exhibit 6-19. Net Benefits for Option 3 for Different VSL Assumptions (Millions 2008$)

| Assumed VSL | Assumed Amount of Nightly Sleep | | |
|---|---|---|---|
| | Low Sleep | Medium Sleep | High Sleep |
| Lower-bound VSL | $410 | $110 | -$190 |
| Mean VSL | $1,100 | $560 | $10 |
| Upper-bound VSL | $1,790 | $1,010 | $220 |

Exhibit 6-20. Net Benefits for Option 4 for Different VSL Assumptions (Millions 2008$)

| Assumed VSL | Assumed Amount of Nightly Sleep | | |
|---|---|---|---|
| | Low Sleep | Medium Sleep | High Sleep |
| Lower-bound VSL | -$440 | -$1,180 | -$1,910 |
| Mean VSL | $900 | -$420 | -$1,750 |
| Upper-bound VSL | $2,250 | $330 | -$1,600 |

## 6.6. SUMMARY OF RESULTS FOR OPTIONS 2 THROUGH 4

In this section, we present a brief summary of the results for Options 2 through 4. First, total costs of Options 2 through 4 are shown in Exhibit 6-21.

Exhibit 6-21. Annualized Costs of All Options (Millions 2008$)

| | Option 2: 10 Hours of Driving Allowed | Option 3: 11 Hours of Driving Allowed | Option 4: 9 Hours of Driving Allowed |
|---|---|---|---|
| Total Costs | $1,030 | $520 | $2,310 |

Next, the total benefits of the different options are shown in Exhibit 6-22. Benefits for Options 2 through 4 are shown using different assumptions on the baseline level of sleep by drivers.

Exhibit 6-22. Benefits of All Options (Millions 2008$)

| Benefit Category | Option 2: 10 Hours of Driving Allowed | Option 3: 11 Hours of Driving Allowed | Option 4: 9 Hours of Driving Allowed |
|---|---|---|---|
| Benefits with Low Sleep | $2,210 | $1,620 | $3,210 |
| Benefits with Medium Sleep | $1,420 | $1,080 | $1,880 |
| Benefits with High Sleep | $620 | $530 | $560 |

Next, Exhibit 6-23 shows the net benefits of the alternative options under the different assumptions of the baseline level of sleep. It is interesting to note that net benefits are negative for Option 2 under the assumption of high levels of baseline sleep for drivers, and are negative for Option 4 under the assumption of medium and high levels of baseline sleep.

Exhibit 6-23. Net Benefits of All Options (Millions 2008$)

| Net Benefit Category | Option 2: 10 Hours of Driving Allowed | Option 3: 11 Hours of Driving Allowed | Option 4: 9 Hours of Driving Allowed |
|---|---|---|---|
| Benefits with Low Sleep | $1,170 | $1,100 | $900 |
| Benefits with Medium Sleep | $380 | $560 | -$420 |
| Benefits with High Sleep | -$410 | $10 | -$1,750 |

## 6.7. MODE SHIFT IMPLICATIONS OF HOS OPTIONS

By reducing driver productivity, the HOS options are expected to increase the costs of freight transportation by truck. These costs, in turn, are likely to be passed on to shippers as rate increases. The increases in rates will tend to change the balance between truck and rail modes of transporting certain commodities, leading to a small shift in freight from truck to rail.

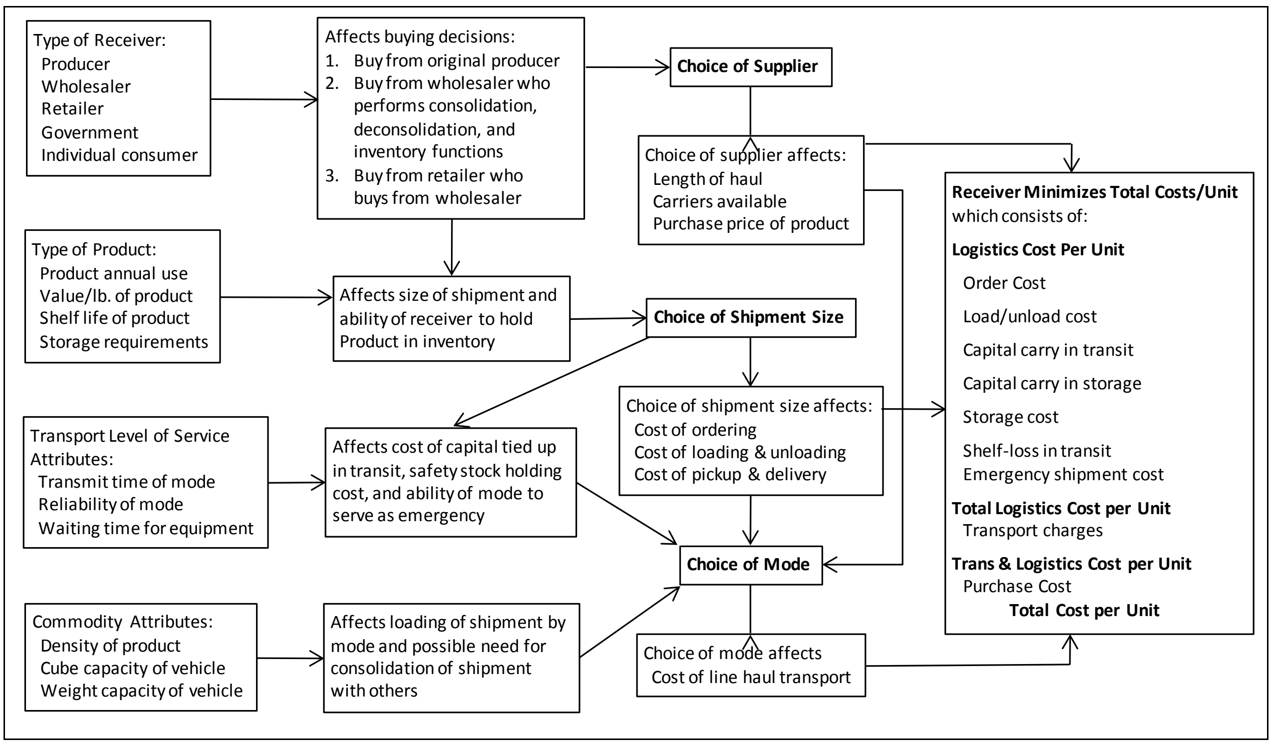
This effect was analyzed in detail for the 2003 HOS rule using a logistics model and taking into account both the effects of productivity changes and the wage increases likely to be needed to attract additional drivers. The following section explains in some detail how that analysis was conducted.

The possibility that changes in HOS could raise the cost of shipping by truck enough to encourage a shift to rail was considered explicitly in FMCSA's analysis of the 2003 HOS rules. This section provides background on that analysis, taken largely from Appendix C to the 2003 RIA, and discusses how the analysis has been applied to the current rules.

### *6.7.1 The Logistics Cost Model*

To determine the effects of the HOS rules on the mode split between truck and rail, we used the Logistics Cost Model (LCM) developed by Paul Roberts. The LCM is a computer model that determines the total logistics cost of transporting a product from a vendor to a receiver. The model determines the lowest cost for ordering, loading, transporting, storing, and holding a product. The shipper is assumed to select the alternative that minimizes total logistics costs. Total logistics cost in this case includes the costs occasioned by service frequency, transit time, reliability, loss and damage, spoilage, and other service-related factors occurring during ordering, transport, or storage. By converting all of these factors into their quantitative impacts on total logistics cost, the tradeoffs among service quality, inventory carrying and transportation charges can be addressed. The variables affecting the choices of the shipper are used to develop each of the individual cost factors listed on the right hand side of Exhibit 6-24.

**Exhibit 6-24. Variables Affecting Choices in Freight Transportation**




These variables are used to write equations for each of the components of total logistics costs as a function of the principal choice variables (i.e., choice of supplier, choice of mode, and choice of shipment size). Changes in transport charges lead to changes in logistics costs to give the total logistics-cost change of an option. Within the model, some "shippers" make new choices and the change in mode share is calculated for the sample in the model.

### *6.7.2 Computational Steps*

The model is organized to use a variety of inputs in a decision process to develop the total logistics costs of a single movement. Computational steps used by the model include the following:

- For a shipper with a given annual use of a particular product, consider alternative mode and shipment size possibilities from the vendor, including LTL, TL, intermodal rail, and rail carload.
- Use rate models for alternative modes to develop transportation charges to the shipper.
- Develop level of service attributes for each source/mode/shipment size, including frequency of service/waiting time, transit time, lead time reliability, and probability of loss and/or damage.
- Combine with attributes of the product being shipped, including units, cube/unit, packed density/unit, value/unit, and shelf life.
- For each alternative source/mode/shipment size, develop the components of total logistics cost to the user of the product for factors including ordering, transporting, carrying costs, storage, and perishability.
- Sum to yield total logistics cost of each alternative.

### *6.7.3 Data Used*

The LCM is a disaggregated model. The model uses a representative sample of individual movements; the data include shipper characteristics, feasible modal alternatives, movement parameters, and commodity attributes for each movement. A disaggregate sample allows the model to examine all of these characteristics and correctly select the mode that minimizes the shipper's total logistics costs.

Two different disaggregate data sources were used to assemble the data set used in the analysis. One is the Rail Carload Waybill Sample. These data are a sample of individual rail movements of various products moving in various car types between various origins and destinations throughout North America. Two data sets were extracted from the Waybill Sample for use in this analysis. The first was a sample of rail carload movements, excluding coal. The second was a set of intermodal rail movements. In all, 2,556 rail movements were used.

A disaggregated sample of long-haul TL movements gathered by the Association of American Railroads in 1994 was used to establish the composition of truck shipments with regard to commodity, equipment type, and shipment size. The sample was obtained by interviews of long-haul truck drivers taken at selected truck stops throughout the United States. The information gathered in each of the interviews included the commodity being carried, the origin, the destination, the type of truck and a variety of information about driver and vehicle. A total of 3,784 movements were eventually used, representing long-haul TL movements throughout the nation. The data set developed by Reebie Associates, reflecting freight flows in 2000, was used to adjust the relative volume of traffic flows among origin-destination pairs to reflect current conditions.

The analysis was limited to movements of 250 miles or more. This was done on the grounds that the probability of switching traffic from truck to rail is effectively zero for moves under 250 miles. Most authorities would assert, in fact, that this probability is quite low for shipments under 500 to 700 miles. Two hundred fifty miles was chosen as a minimum, however, to ensure a thorough analysis. Data on length of freight movements from the 1997 CFS were used to adjust the disaggregate data set so that the sample of moves over 250 miles would conform to actual practice in the relative volumes of such traffic among city pairs.

### *6.7.4 Results of Using the Logistics Cost Model*

Results from the analysis allowed us to observe which individual moves are diverted from truck as the cost of trucking goes up, and which are diverted to truck when the cost of trucking drops. For our purposes the results are aggregated and expanded to determine the increase or decrease in truck usage as a result of changes in HOS policy. Exhibit 6-25 below shows the result of exercising the model over a range of increases and decreases in overall truck costs. Five cases are covered: the base case (the current level of truck cost); 1.0 and 2.0 percent increases from the base cost, and 1.0 and 2.0 percent decreases from the base cost. The results are presented in Exhibit 6-25. Both truck shipments and tons are greater in the cases with costs below the base case, and lower in the cases with higher costs, but to only a small degree.

**Exhibit 6-25. Summary of Model Runs**

| **Observations** | Rail | Intermodal | Truck | Totals |
|---|---|---|---|---|
| Base Case | 547 | 2,009 | 3,784 | 6,340 |
| 1.01*Base | 552 | 2,070 | 3,718 | 6,340 |
| Base*1.02 | 560 | 2,111 | 3,669 | 6,340 |
| Base*.99 | 537 | 1,957 | 3,846 | 6,340 |
| Base*.98 | 519 | 1,921 | 3,900 | 6,340 |

| **Tons** | Rail tons/yr | Intermodal tons/yr | Truck tons/yr | Totals |
|---|---|---|---|---|
| **No. Tons in sample** | | | | |
| Base Case | 2,221,349 | 2,710,958 | 8,307,492 | 13,239,799 |
| 1.01*Base | 2,238,476 | 2,801,360 | 8,199,963 | 13,239,799 |
| Base*1.02 | 2,260,564 | 2,870,570 | 8,108,665 | 13,239,799 |
| Base*.99 | 2,181,121 | 2,623,090 | 8,435,588 | 13,239,799 |
| Base*.98 | 2,128,862 | 2,543,339 | 8,567,599 | 13,239,799 |

The results of these analyses were used to estimate elasticities for the response of total truck and rail traffic to changes in overall truck costs. The ratio of the percentage change in truck shipments and tons shipped, per one percent change in truck rates, was approximately 1.4. This measure of elasticity was used, in turn, to estimate impacts on truck and rail traffic for each of the HOS rule options.

In the analysis for the 2003 HOS rules, the proposed Option was estimated to reduce truck rates by 0.3 percent; applying the elasticity of 1.4 to this reduction would lead to about a 0.4 percent increase in the relevant LH segment (i.e., those greater than 250 miles). Across all LH segments, the increase would be a somewhat smaller 0.25 percent.

### *6.7.5 Scaling of the Results of the Mode Shift Analysis*

Because the measured effect in that analysis was small, FMCSA did not consider it necessary to repeat the analysis in detail. Rather, the mode shift effect of the current proposal has been estimated by scaling the results of the previous analysis in recognition of the differences between the costs of the options in 2003 and 2010.

In the analysis for 2003, both the Parents against Tired Truckers (PATT) Option and the Full Compliance Baseline were found to reduce LH truck VMT because of their costs relative to the Status Quo Baseline (which was also the No Action Alternative). As shown in the Environmental Assessment for the 2003 HOS Rules, the PATT Option would lead to a LH truck VMT reduction of 1.35 percent, while the corresponding LH truck VMT reduction for the Full Compliance Baseline would be only 0.84 percent [FMCSA (2002b)].[27] The difference is a reduction in LH truck VMT by an incremental 0.51 percent. The difference in productivity for LH truck drivers between these two scenarios was 4 percent, as shown by the 4 percent increase in drivers required to transport a given amount of freight under the PATT Option relative to the Full Compliance Baseline.[28] Dividing the 0.51 percent change in VMT by the 4 percent drop in productivity yields just under 0.13, which is the ratio of VMT changes to productivity changes that is used in the current analysis. Thus, a reduction in productivity of 2.8 percent for Option 2 is projected to lead to a small mode shift that would reduce LH VMT by 0.36 percent (0.13 x 2.8). This small drop in VMT would offset some of the need for additional drivers caused by the reduction in LH productivity. Compared to Option 2, Option 3 would lead to a drop in LH VMT and drivers about half as great (in line with its lower costs) and Option 4 would lead to drop about twice as great.

## 6.8. CHANGE IN DRIVERS

The operational changes resulting from the HOS rule provisions reduce the productivity of drivers that are close to or above the maximum daily driving and work time limits. Assuming there is no change (except for some mode shifting as discussed above) in the amount of freight that needs to be moved, new drivers will need to enter the industry under Options 2 through 4.

To calculate the number of new drivers that would be needed for Options 2 through 4, we multiplied the total number of drivers (1,600,000) by the estimated percent impact on productivity. This calculation resulted in an estimate of the gross number of new drivers that would be needed for Options 2 through 4. For example, for Option 2 there is an estimated 2.78 percent impact on industry productivity. The gross number of new drivers needed for this regulatory Option is thus 44,409 (1,600,000 x 2.78%).

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[27] Because some of the projected impact on LH VMT was assumed to result indirectly from changes in short-haul productivity, operating through the labor market, this estimate of the mode shift consequences of the productivity changes in the LH segment is slightly overstated.

[28] 2003 HOS RIA [FMCSA (2002a)], Exhibit 9-1, Changes in Drivers Needed in Response to HOS Limits Relative to Current Rules with Full Compliance.

We next calculated the net number of new drivers by accounting for the mode shift effects. Using the ratio of VMT change to productivity change discussed above results in 87 percent (100% - 13%) of the total number of new drivers needed after accounting for mode shift effects. For example, for the option 2, the net number of new drivers needed is 38,636 (44,409 x 87%). Exhibit 6-26 below presents the gross and net number of new drivers needed for Options 2 through 4.

Exhibit 6-26. Gross and Net Numbers of New Drivers Needed

| Net Benefit Category | Option 2: 10 Hours of Driving Allowed | Option 3: 11 Hours of Driving Allowed | Option 4: 9 Hours of Driving Allowed |
|---|---|---|---|
| Estimated Productivity Impact (A) | 2.78% | 1.34% | 6.36% |
| Gross Number of New Drivers Needed (B = A x 1,600,000) | 44,409 | 21,496 | 101,735 |
| Net Number of New Drivers Needed (C = B x 87%) | 38,636 | 18,701 | 88,510 |

## 6.9. Safety Impacts of New Drivers and Mode Shifts

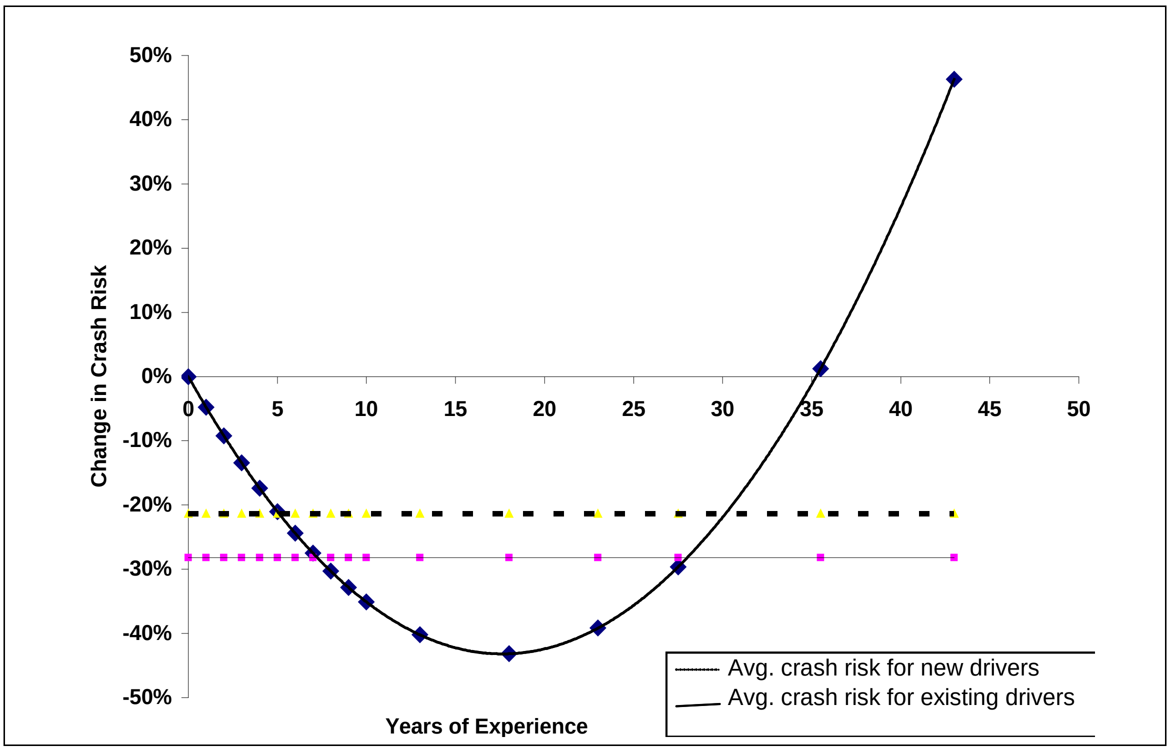
As stated in Section 6.4, both the small projected shift from truck to rail and the substitution of new drivers for some of the work currently done by experienced drivers can be expected to have minor safety consequences. This section goes into more detail on the past analyses that found that these effects largely offset each other.

### *6.9.1 Safety Impacts of New Drivers*

The analysis for the 2003 HOS rules explicitly considered the safety consequences of expanding the driver population by hiring inexperienced drivers. Data from a survey by the University of Michigan Trucking Industry Program (UMTIP) on years of experience and crashes showed rapidly declining crash risk as new drivers gain experience, and then a gradual increase as the drivers age [Belman, D.L. (1997-1999)]. These data were used to develop the quadratic function shown in Exhibit 6-27. The function, in turn, was used to estimate the average risk over the next 10 years for both new drivers and drivers who start with four years of experience, each relative to the risks of a brand-new driver. These calculations showed that the average risk for new drivers for the first 10 years of their experience is 19.6 percent below the first year, and the 10-year average of drivers who start with 4 years of experience is 31.5 percent below the first year. Blending those brand-new and somewhat new drivers in the ratio of 85%/15% (based on conversations with industry sources) gave a weighted average of 21.4 percent below the first year for the new drivers over the first 10 years.

To compare this risk reduction level to that for the population as a whole, the quadratic function was combined with data on driver experience from the Driver Fatigue, Alertness and Countermeasures Study (DFACS) [Abrams, C., *et al*. (1997)]. Plugging various numbers of years of experience into the quadratic function for reduction of risk below the first year, and then weighting by the distribution of the existing driver population, the typical existing driver was found to be 28.2 percent less likely to crash than a brand new driver. The difference between the new and the existing drivers, then, is (28.2% - 21.4%) or 6.8 percent. This difference is then the predicted increase in crash risk for the new drivers relative to the existing drivers. Because this risk increase applies only to the new drivers, who constitute a fraction of the total population, the effect on total crash damages and total fatalities is very small. In the 2003 RIA, the impact was expressed in terms of changes in benefits. The proposed Option was projected to lead to a reduction in LH drivers of 3.9 percent, or 58,500; applying the slightly lower crash risk for existing drivers to this reduction in new drivers led to a projected reduction in total LH crash damage of 6.8% x 3.9% or 0.265 percent. At the time, total damages from LH crashes were estimated at $18.7 billion per year, so the reduction of 0.265 percent translated to a reduction in crash damage of about $50 million per year. Alternatively, the effect of reducing the driver population by 58,500 could have been translated into lives saved: 0.265 percent of the 3,100 fatalities in LH crashes equals about 8 lives.

Exhibit 6-27. Effect of Experience on Crash Risk




Source: from Exhibit 8-11 of the 2003 RIA; ICF analysis of UMTIP and DFACS data.

### *6.9.2 Safety Impacts of Mode Shift*

Counteracting the change in risk from different numbers of new drivers is the change in truck VMT that results from mode shifts between truck and rail. As presented in Section 6.7.4 above, the mode shift analysis for the 2003 HOS rules found that the proposed Option would increase truck VMT by about 0.25 percent. Assuming that, other things equal, crashes are proportional to VMT, this increase would increase fatalities related to LH crashes by 0.25 percent of their baseline level of about 3,100, and increase total damages from LH crashes by 0.25 percent of

$18.7 billion. Multiplying 0.25% x 3,100 gives an estimated increase of just below 8, and 0.25% x $18.7 billion gives an increase of $47 million.

These changes would cancel out, almost exactly, the benefits of reducing the number of slightly riskier new drivers, which as noted were 8 lives and $50 million. The small magnitude of the effects of the new drivers on the one hand and the mode shift on the other, the fact that they were found to operate in opposite directions, and appeared (when estimated carefully) to offset each other almost completely, led FMCSA to conclude that explicitly analyzing these effects for the 2010 HOS Rule was unnecessary.

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# 7. Regulatory Flexibility Analysis

As required by the Regulatory Flexibility Act, this chapter analyzes the impact of the proposed changes to the HOS regulations on small entities. After a description of why action is being taken by the Agency, we then discuss the possible number of affected small entities. We next estimate the impact of the new HOS rule provisions on small carriers in the first year in which the rule would be in effect for Options 2 and 3. We then estimate the annual burden on small entities over the first ten years of the rule being in effect. Lastly, we discuss the reporting, recordkeeping, and other compliance requirements of the proposed rule, discuss whether any other Federal regulations overlap with the proposed rule, and discuss the consideration of alternatives to minimize the impact of the proposed rule on small entities.

## 7.1. A Description of the Reasons Why Action by the Agency Is Being Considered

The goals of the proposed changes to the HOS rule are to improve safety while ensuring that the requirements would not have an adverse impact on driver health. The proposed rule would also provide drivers with the flexibility to obtain rest when they need it and to adjust their schedules to account for unanticipated delays. The impact of HOS rules on CMV safety is difficult to separate from the many other factors that affect heavy-vehicle crashes. While the Agency believes that the data show no decline in highway safety since the implementation of the 2003 HOS rule and its re-adoption in the 2005 HOS rule, the 2007 IFR, and the 2008 HOS rule (73 FR 69567, 69572, November 19, 2008), the total number of crashes, though declining, is still unacceptably high. FMCSA believes that the modified HOS rules proposed in the accompanying NPRM, coupled with the Agency's many other safety initiatives and assisted by the actions of an increasingly safety-conscious motor carrier industry, would result in continued reductions in fatigue-related CMV crashes and fatalities. Furthermore, this proposed rule is intended to protect drivers from the serious health problems associated with excessively long work hours, without significantly compromising their ability to do their jobs and earn a living.

## 7.2. A Succinct Statement of the Objectives of, and Legal Basis for, the Proposed Rule

The objectives of the proposed rule are to reduce large-truck involved crashes – especially those where fatigue is a causative factor – and protect drivers against the adverse health impacts of working excessively long hours. This proposed rule is based on the authority of the Motor Carrier Act of 1935 and the Motor Carrier Safety Act of 1984 (1984 Act). The Motor Carrier Act of 1935 provides that "The Secretary of Transportation may prescribe requirements for (1) qualifications and maximum hours of service of employees of, and safety of operation and equipment of, a motor carrier; and, (2) qualifications and maximum hours of service of employees of, and standards of equipment of, a motor private carrier, when needed to promote safety of operation" (Section 31502(b) of Title 49 of the United States Code (49 U.S.C.)).

The HOS regulations proposed today concern the "maximum hours of service of employees of . . . a motor carrier" (49 U.S.C. 31502(b)(1)) and the "maximum hours of service of employees of . . . a motor private carrier" (49 U.S.C. 31502(b)(2)). The adoption and enforcement of such rules were specifically authorized by the Motor Carrier Act of 1935. This proposed rule rests on that authority.

The 1984 Act provides concurrent authority to regulate drivers, motor carriers, and vehicle equipment. It requires the Secretary of Transportation to "prescribe regulations on commercial motor vehicle safety. The regulations shall prescribe minimum safety standards for commercial motor vehicles." Although this authority is very broad, the 1984 Act also includes specific requirements:

> At a minimum, the regulations shall ensure that (1) commercial motor vehicles are maintained, equipped, loaded, and operated safely; (2) the responsibilities imposed on operators of commercial motor vehicles do not impair their ability to operate the vehicles safely; (3) the physical condition of operators of commercial motor vehicles is adequate to enable them to operate the vehicles safely; and (4) the operation of commercial motor vehicles does not have a deleterious effect on the physical condition of the operators (49 U.S.C. 31136(a)).

The United States Court of Appeals for the District of Columbia Circuit (D.C. Circuit) has said with regard to 49 U.S.C. 31136(a)(4) that:

> The statute requires the agency to consider the impact of the rule on 'the physical condition of the operators,' not simply the impact of driver health on commercial motor vehicle safety. . . . It is one thing to consider whether an overworked driver is likely to drive less safely and therefore cause accidents. Whether overwork and sleep deprivation have deleterious effects on the physical health of the driver is quite another (Public Citizen *et al*. v. FMCSA, 374 F.3d 1209, 1217 (D.C. Circuit 2004).

This proposal would improve both highway safety and the health of CMV drivers.

This proposed rule is also based on the authority of the 1984 Act and addresses the specific mandates of 49 U.S.C. 31136(a)(2), (3), and (4). Section 31136(a)(1) of 49 U.S.C. mainly addresses the mechanical condition of CMVs, a subject not included in this rulemaking. To the extent that the phrase "operated safely" in paragraph (a)(1) encompasses safe driving, this proposed rule also addresses that mandate.

Before prescribing any regulations, FMCSA must also consider their "costs and benefits" (49 U.S.C. 31136(c)(2)(A) and 31502(d)). Those factors are also discussed in this proposed rule.

### 7.3. A Description of and, Where Feasible, an Estimate of the Number of Affected Small Entities to Which the Proposed Rule Will Apply

The HOS regulations apply to both large and small motor carriers. The Small Business Administration defines a small entity in the truck transportation sub-sector (North American Industry Classification System [NAICS] 484) as an entity with annual revenue of less than $25.5 million [13 CFR 121.201]. Using data from the 2007 Economic Census, FMCSA estimated that the average carrier earns almost $200,000 in annual revenue per truck for firms with multiple power units,[29] suggesting that a typical carrier that qualifies as a small business would have fewer than 128 ($25.5 million / $200,000) power units (i.e., trucks or tractors) in its fleet. Also using data from the 2007 Economic Census, FMCSA estimated that sole proprietorships earned approximately $85,000 in annual revenue.[30]

To determine the number of affected small entities, we used the analysis conducted by FMCSA for the Unified Carrier Registration (UCR) rule [FMCSA (2010)]. The economic analysis for the UCR rule divided carriers into brackets based on their fleet size (i.e., number of power units), and estimated the number of carriers in each bracket. These brackets and their corresponding numbers of carriers are shown in Exhibit 7-1. According to these estimates and the above-mentioned characterizations of small entities in the trucking industry, all of the carriers in Brackets 1 through 4 would qualify as small entities, as would many of the carriers in Bracket 5. Therefore, this analysis estimates that between 422,196 (Brackets 1 through 4) and 425,786 (Brackets 1 through 5) small entities would be affected by the HOS rule changes. This range may overstate the number of affected small entities because many private carriers with small fleets may not qualify as small businesses because their primary business is not the movement of freight. These private firms would thus have other sources of revenue and fall under different NAICS codes.

Exhibit 7-1. Number of Carriers by Fleet Size (From FMCSA's Analysis of the UCR Rule)

| Bracket | Fleet Size | Number of Carriers |
|---|---|---|
| 1 | 1 | 194,425 |
| 2 | 2 – 5 | 145,266 |
| 3 | 6 – 20 | 65,155 |
| 4 | 21 – 100 | 17,350 |
| 5 | 101 – 1,000 | 3,590 |
| 6 | 1,001 – More | 292 |
| **Total** | | **433,535** |

Exhibit 7-2 below presents figures for private carriers by NAICS code for industries with large numbers of drivers (and hence the likelihood of large numbers of fleets). The table includes the total number of CMV drivers working in each industry, the percentage of payroll those drivers account for, and the payroll of those industries as a percent of total industry revenue. Some of these industries have SBA size thresholds that are considerably lower than the threshold for truck

[29] As shown in the "2007 Economic Census," the entire trucking industry (NAICS code 484) generated revenue of $228,907 million (in 2006 dollars). FMCSA then used 2007 Economic Census data for NAICS code 484 to derive a total estimate of 1,183,000 trucks in the for-hire sector. FMCSA then divided total revenue by the total number of trucks to obtain an estimate of average revenue of $193,000 in 2006 dollars, or $199,967 inflated to 2008 dollars using the Gross Domestic Product (GDP) Deflator (http://cost.jsc.nasa.gov/inflateGDP.html). This $199,967 value was rounded to $200,000 in the analysis.

[30] There were 499,706 individual proprietorships in the "truck transportation" NAICS code with total revenue of $41,110 million. Dividing the total revenue by the total number of firms resulted in average revenue per firm of $82,269 in 2006 dollars, or $85,239 when inflated to 2008 dollars using the GDP Deflator (http://cost.jsc.nasa.gov/inflateGDP.html). This $85,239 value was rounded to $85,000 in the analysis.

transportation, strongly suggesting that many firms in these industries that would be considered small using the threshold of 128 power units are actually large. For example, a wholesaler with 128 trucks is certainly a large firm because it will have more than 100 employees. Other industries have thresholds as high as 1,500 full time equivalent employees (FTEs); a firm in one of these industries might rank as small with even more than 128 power units if the number of power units in its fleet were large compared to the size of its workforce (e.g., if it had 300 power units, and only three employees per power unit, it could be considered small in an industry with a threshold of 1,500 FTEs). From Exhibit 7-2, however, this circumstance is not likely to be common: in firms in NAICS 21 and 31-33, which have high FTE thresholds, drivers make up only a very small percentage of the workforce. Thus, firms with a substantial numbers of power units are likely to have much larger labor forces, and are therefore likely to rank as large firms. Given these considerations, we are, if anything, over-counting the number of private carriers that would qualify as small businesses.

Exhibit 7-2. Private Carriers and Drivers by Industry

| NAICS | Industry | SBA Standard | # Drivers | Drivers as % of All Employees | Payroll as % Revenues |
|---|---|---|---|---|---|
| 21 | Mining, Quarrying, and Oil and Gas Extraction | 500 FTE | 29,900 | 4.17% | 10% |
| 23 | Construction | $14m-$33.5m | 127,200 | 1.76% | 19% |
| 31-33 | Manufacturing | 500-1,500 FTE | 238,600 | 1.78% | 11% |
| 42 | Wholesale | 100 FTE | 509,000 | 8.53% | 5.5% |
| 44-45 | Retail | $7 m - $29m | 307,900 | 2.01% | 10% |
| 53 | Real Estate and Leasing | $7m - $25m | 40,500 | 1.9% | 18% |
| 56 | Administrative and Support and Waste Management and Remediation Services | $7m – $35.3m | 132,300 | 1.64% | 46% |
| 722 | Food Services | $7m | 175,400 | 1.82% | 29% |
| 81 | Other Services | $7m | 44,000 | 0.80% | 24% |

### *7.3.1. First Year Impacts on Small Entities*

Affected small entities would incur several types of costs as a result of the HOS rule provisions. First, as discussed in the HOS RIA, carriers would incur annual costs due to losses in productivity. As discussed in the HOS RIA, these productivity impacts are roughly $990 million per year for Option 2 and $480 million per year for Option 3. We divided this total productivity impact by the approximate number of long-haul drivers (1,600,000) to obtain an annual per driver productivity impact of approximately $620 for Option 2 and $400 for Option 3. We then converted these per driver impacts to per power unit impacts (shown below in Exhibit 7-3). For sole proprietorships, we assumed for this analysis that these were single power unit firms and there was one driver per tractor. The total annual operational cost for sole proprietorships was thus $620 ($620 x 1) for Option 2 and $300 ($300 x 1) for Option 3.[31] For firms with multiple

[31] In this analysis, we consider sole proprietorships separately due to the fact that these firms tend to have low revenues and are thus impacted by the proposed rule differently than larger firms. We have assumed that sole

power units, this analysis assumes that multiple unit carriers have 1.1 drivers per power unit [FMCSA (2007d)]. The annual per power unit operational cost for firms with multiple power units was thus $682 ($620 x 1.1) for Option 2 and $330 ($300 x 1.1) for Option 3.

In addition to the productivity impacts, each carrier would incur one-time costs for training in the requirements of the new rule. To estimate the training cost, we used information from Agency personnel who participated in previous HOS retraining efforts to determine that each driver would need to take a one-time 2-hour training course to ensure compliance with the new rule provisions. As described in Chapter 6 of the RIA, we used a loaded average hourly rate of $23.96 (wages plus fringe benefits) for the industry. The 2-hour training course thus resulted in a cost of approximately $48 per driver.

Carriers would incur additional one-time costs for software reprogramming and other transition costs. As discussed in the RIA, reprogramming and other transition costs were estimated using information obtained from the HOS listening sessions conducted in various locations in early 2010. Based on information from these sessions, we assumed that the total one-time training, reprogramming, and other transition costs were about $200 per driver (including the $48 training cost discussed above). For sole proprietorships, we again assumed one driver per power unit for a total one-time cost of $200 per power unit. We view this estimate as conservative due to the fact that many firms will not incur any programming costs. We again assumed that carriers with multiple units have 1.1 drivers per power unit, for a total one-time cost of $220 per power unit [FMCSA (2007d)]. These one-time costs for sole proprietorships and multiple power unit firms are the same for Options 2 and 3, and are shown below in Exhibit 7-3.

To estimate the first-year costs per-power unit for affected firms, the annual and one-time costs for Options 2 and 3 were summed as shown in Exhibits 7-3 and 7-4. For Option 2, this calculation resulted in a total first-year cost to sole proprietorships of $820 per power unit in the first year, and a total first-year cost to firms with multiple power units of $902 per power unit. For Option 3, this calculation resulted in a total first-year cost to sole proprietorships of $500 per power unit in the first year, and a total first-year cost to firms with multiple power units of $550 per power unit.

Exhibit 7-3. First-Year Costs to Affected Firms per Power Unit for Option 2

| Type of Cost | Cost per Power Unit (Sole Proprietorship) [a] | Cost per Power Unit (Multiple Power Unit Firm) [a] |
|---|---|---|
| Annual Operating Cost (A) | $620 | $682 |
| One Time Training, Reprogramming, and Other Costs (B) | $200 | $220 |
| **Total First Year Cost (A + B)** | **$820** | **$902** |

[a] FMCSA analysis

proprietorships have one power unit, but their defining characteristic is their average revenues and not the number of power units they have.

Exhibit 7-4. First-Year Costs to Affected Firms per Power Unit for Option 3

| Type of Cost | Cost per Power Unit (Sole Proprietorship) [a] | Cost per Power Unit (Multiple Power Unit Firm) [a] |
|---|---|---|
| Annual Operating Cost (A) | $300 | $330 |
| One Time Training, Reprogramming, and Other Costs (B) | $200 | $220 |
| **Total First Year Cost (A + B)** | **$500** | **$550** |

[a] FMCSA analysis

Next, we compared the estimated first-year costs to the average revenue for sole proprietorships and multiple power unit firms for Options 2 and 3 (shown in Exhibits 7-5 and 7-6). As noted earlier, average revenues for different sized firms were taken from 2007 Economic Census data.[32] For Option 2, the first year costs of the proposed rule changes would be equal to 0.96 percent of average revenue for sole proprietorships, and 0.45 percent of average revenue for multiple unit carriers. For Option 3, the first year costs of the proposed rule changes would be equal to 0.59 percent of average revenue for sole proprietorships, and 0.28 percent of average revenue for multiple unit carriers. Thus, when looking only at first year costs for each of the considered regulatory options, the new HOS rule is not expected to have a significant impact on the average sole proprietorship or firm with multiple power units. Because of variability in both the first-year costs and the average revenues to which they are compared, however, the impact on firms would vary. It is thus likely that the impact of the first year costs would be higher for some carriers, rising to a level that could be considered significant.

Exhibit 7-5. Impact of First-Year Costs on Affected Firms for Option 2
(as a Percent of Average Revenue)

| Type of Cost | Sole Proprietorships | Multiple Power Unit Firms |
|---|---|---|
| First Year Cost Per Power Unit (A)[a] | $820 | $902 |
| Annual Revenue Per Power Unit (B)[b] | $85,239 | $199,967 |
| First Year Cost Impact as a Percentage of Annual Revenue (A / B) | 0.96% | 0.45% |

[a] FMCSA analysis

[b] FMCSA analysis of 2007 Economic Census data

[32] To be conservative in assessing potential impacts, the revenues per power unit are based only upon for-hire firms (that is, those in Truck Transportation). As shown in Exhibit 7-2, drivers make up only a small fraction of the labor force in other industries, which underlines the point that transportation is a small part of their operations. When the Agency has looked at the impact on private carriers in relation to their revenue in the past, the percentage impact of costs to private carriers as a share of revenue have been generally been an order of magnitude smaller than the impacts on for-hire trucking firms.

Exhibit 7-6. Impact of First-Year Costs on Affected Firms for Option 3 (as a Percent of Average Revenue)

| Type of Cost | Sole Proprietorships | Multiple Power Unit Firms |
|---|---|---|
| First Year Cost Per Power Unit (A)[a] | $500 | $550 |
| Annual Revenue Per Power Unit (B)[b] | $85,239 | $199,967 |
| First Year Cost Impact as a Percentage of Annual Revenue (A / B) | 0.59% | 0.28% |

[a] FMCSA analysis

[b] FMCSA analysis of 2007 Economic Census data

### *7.3.2. Annual Burden on Affected Small Entities*

To analyze the annual burden on affected small entities for Options 2 and 3, we amortized the one-time costs over a 10-year period, assuming a 7 percent discount rate. As shown in Exhibit 7-7 for Option 2, the sum of the annual operating costs and the amortized one-time costs resulted in an annual burden of $647 per year over 10 years for sole proprietorships, and an annual burden of $711 per year over 10 years for firms with multiple power units. As shown in Exhibit 7-8 for Option 3, the sum of the annual operating costs and the amortized one-time costs resulted in an annual burden of $327 per year over 10 years for sole proprietorships, and an annual burden of $359 per year over 10 years for firms with multiple power units.

Next, we compared the annual burden to the average annual revenues of affected firms. As shown in Exhibit 7-7, the annual costs of Option 2 are 0.76 percent of average annual revenue for sole proprietorships, and 0.36 percent of average revenue for carriers with multiple power units. As shown in Exhibit 7-8, the annual costs of Option 3 are 0.38 percent of average annual revenue for sole proprietorships, and 0.18 percent of average revenue for carriers with multiple power units. These percentages fall below what the Agency views as a reasonable threshold for a significant impact. However, as mentioned above, the impact may vary across carriers. Therefore, the annual impact of the regulations on some affected carriers may be significant in relation to their revenue.

Exhibit 7-7. Annual Impact of Costs on Firms over 10 Years for Option 2

| Type of Cost | Sole Proprietorships | Multiple Power Unit Firms |
|---|---|---|
| Annual Cost per Power Unit (One Time Costs Amortized Over 10 Years) (A) [a] | $647 | $711 |
| Annual Revenue per Power Unit (B) [b] | $85,239 | $199,967 |
| Annual Cost Impact as a Percentage of Annual Revenue (A / B) | 0.76% | 0.36% |

[a] FMCSA analysis

[b] FMCSA analysis of 2007 Economic Census data

Exhibit 7-8. Annual Impact of Costs on Firms over 10 Years for Option 3

| Type of Cost | Sole Proprietorships | Multiple Power Unit Firms |
|---|---|---|
| Annual Cost per Power Unit (One Time Costs Amortized Over 10 Years) (A) [a] | $327 | $359 |
| Annual Revenue per Power Unit (B) [b] | $85,239 | $199,967 |
| Annual Cost Impact as a Percentage of Annual Revenue (A / B) | 0.38% | 0.18% |

[a] FMCSA analysis

[b] FMCSA analysis of 2007 Economic Census data

### *7.3.3. Discussion of the Impact on Affected Small Entities*

The analysis of the impact of the HOS rule on small entities shows that, while it is unlikely for the regulatory options to have a significant impact on most small entities, FMCSA cannot certify that there would be no significant impacts. For a typical firm, the first year costs of Options 2 and 3 are below 1 percent of revenues, as are the average annual costs when the costs are spread over 10 years.

However, projecting the distribution of impacts across carriers, few of which fit the definition of typical, is rendered more difficult by the variability in both costs and revenues. The new HOS rule provisions are designed to rein in the most extreme patterns of work while leaving more moderate operations largely unchanged. As a result, a substantial majority of the costs of the rule are projected to fall on the sixth of the industry currently logging the most hours per week. Thus, most carriers are likely to be almost unaffected, while a minority would experience productivity impacts – and hence costs – well above the industry average.

Average revenues presumably range widely as well, meaning that the ratio of costs to revenues is difficult to characterize. Because greater work intensities are likely to generate greater revenues, though, the impacts and revenues per power unit are likely to be positively correlated: the carriers for which productivity is curtailed the most and therefore which would incur the greatest costs would be likely to have unusually large revenues per power unit as well.

These heavily affected carriers would still be likely to face costs that exceed the threshold used to define significant impacts. On the other hand, they could also have unusually high rates of profit in the baseline; because their drivers are currently putting in the most hours of work per week, they are able to spread their fixed costs over more hours. In other words, most of the impacts of the new HOS rule are likely to fall on the carriers with the greatest revenues and profit potential in the industry. These circumstances should reduce concern that large numbers of small carriers would experience significant impacts.

Another consideration in assessing the seriousness of the rule's impacts is that the industry is now gaining strength after an unusually deep recession. That recession depressed demand for transportation services. As the economy recovers, demand for the motor carrier industry is likely to recover as well, meaning that the new HOS rule's impacts could be experienced more as limitations on the potential growth in revenues than absolute reductions.

In recognition of the fact that the rule may significantly impact small entities, FMCSA explored options for decreasing the burden on small entities. FMCSA did not consider the Option of exempting small entities from this rule because doing so would substantially decrease the safety benefits of the rule due to the large number of drivers working for small entities. The rule addresses fatigue of individual drivers, which is not affected by the size of the employer. Several provisions of the proposed rule, including the restart provision, the opportunity for 16-hour driving windows, and the break provisions, however, were designed to afford maximum flexibility for drivers who work close to the legal maximum limits, thus reducing the productivity impacts on carriers while still realizing the safety benefits of the new rule. FMCSA expects small carriers and owner-operators to be among the main beneficiaries of these provisions.

## 7.4. A Description of the Projected Reporting, Recordkeeping, and Other Compliance Requirements of the Proposed Rule, Including an Estimate of the Classes of Small Entities Which Will Be Subject to the Requirement and the Type of Professional Skills Necessary for the Preparation of the Report or Record

The proposed rule does not change recordkeeping or reporting requirements. Drivers are required, by current rules, to keep records of duty status that document their daily and weekly on-duty and driving time, and submit these records of duty status to their employing motor carrier on a bi-weekly basis. This rule would not change or add to this recordkeeping requirement for drivers or carriers. Drivers in all segments of the industry, including independent owner-operators, are well accustomed to complying with these recordkeeping and reporting requirements, and no professional skill over and above those skills that drivers already possess would be necessary for preparing these reports. All small entities within the industry would be subject to these rules. The type and classes of these small entities are described in the previous section of this analysis.

## 7.5. An Identification, to the Extent Practicable, of All Relevant Federal Rules Which May Duplicate, Overlap, or Conflict With This Proposal

The Agency is unaware of any federal rules which may duplicate, overlap, or conflict with the proposed rule. The Agency seeks public comment on all aspects of this RFA analysis.

## 7.6. A Description of any Significant Alternatives to the Proposed Rule Which Minimize any Significant Impact on Small Entities

The Agency did not identify any significant alternatives to the proposed rule that could lessen the burden on small entities without compromising its goals. This rule is targeted at preventing driver fatigue, and the Agency is unaware of any alternative to restricting driver work that the Agency has authority to implement that would address driver fatigue. This rule impacts motor carrier productivity proportional to the number of drivers a motor carrier employs and the intensity of the schedules that motor carrier's drivers work. It is not obvious that productivity losses would be greater for small entities than for larger firms. To the extent that drivers working for a small entity work more intense schedules, that entity may experience greater productivity losses than a carrier whose drivers work less intensely on a daily and weekly basis.

However, there appears to be no alternative available to the Agency that would limit driver fatigue while allowing more work. To improve public safety, all drivers, regardless of the size of the carrier they work for, must work within reasonable limits.

The recordkeeping and reporting burdens related to this rule would also affect entities proportional to the number of drivers they employ, and therefore does not disproportionately affect small motor carriers in any way. As noted above, drivers in all segments of the industry, working for entities of all sizes, are accustomed to compiling and submitting records of duty status on a regular basis. This rule would therefore not place an undue recordkeeping or reporting burden on smaller entities.

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